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Food and habitat use within the fish assemblages of the lower Slave River, Northwest Territories

by

Alison Susanne Little ©

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **Food and habitat use within the fish assemblages of the lower Slave River, Northwest Territories** submitted by Alison S. Little in partial fulfillment of the requirements for the degree of Master of Science, Environmental Biology and Ecology.

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Abstract

Increased industrial activities on the Peace and Athabasca River systems have raised concerns about cumulative impacts on fish and water resources downstream in the Slave River, of Alberta and the Northwest Territories. Because very little information is available on the fish assemblage in this system, I examined spatial and temporal patterns of food and habitat use from three locations along the Slave River system to assess trophic and habitat relationships within the assemblages. Habitats used by the fishes of the three study areas were ecologically distinct, primarily due to differences in discharge and the amounts of vegetation. However, within each of the study areas, finer-scaled differences in habitat use were evident among individual species. Few species appeared to be influenced by the same combinations of habitat variables, thus interactions between species in habitat use are probably low. Dietary overlap was also generally low. Most fish in the Slave River are generalist, opportunistic feeders, consuming a number of different prey, and the importance of these prey varies spatially and seasonally with variation in their abundance in the environment.

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Chapter 1. GENERAL INTRODUCTION

Introduction

The Slave River of northern Alberta and the Northwest Territories, Canada, is a relatively pristine large northern river in the Mackenzie River Basin, providing important traditional fishing grounds for aboriginal subsistence and commercial fisheries (Bodden 1980). However, as industrial activities expand on the Peace and Athabasca Rivers upstream of the Slave River, there is increased concern from northern residents about the quality of water and fish resources in this system. Often, predators at the top of aquatic food chains are most severely affected by the bio-accumulation of contaminants, and it is these top predators that are most heavily used by northern residents.

Since accumulation of contaminants into fish may be influenced by the trophic level at which they live, including the spatial and temporal patterns of their feeding (MacDonald and Smith 1993), it is essential to quantify these patterns, and patterns of habitat use, for the fish assemblages in this system. Also, since very few studies have previously been conducted on the Slave River, there is a real need for important baseline information on resource use by fishes, so we can have a better understanding of the relative roles that biotic and abiotic factors play in structuring the fish assemblages in this system. This knowledge should contribute to a better overall understanding of how contaminants may bio-magnify within the food web and how physical alterations to the Slave River (i.e., construction of dams) may alter the structure of fish assemblages.

Very little is known about processes structuring fish assemblages in large rivers, particularly large, northern rivers. Abiotic factors such as discharge rates, substrate type, channel morphology and the degree of turbidity may ultimately influence the productivity of a system (Welcomme 1985; Bodaly *et al.* 1989; Ryder and Pesendorfer 1989; Johnson *et al.* 1995). Furthermore, the productivity of a system may influence biotic factors, such as the distribution and abundance of organisms present and thereby influence community structure.

This study will begin by examining the productivity of large rivers and how this interacts with biotic and abiotic factors to influence the distribution and abundance of species. The main body of the thesis (Chapter 2) quantifies spatial and temporal patterns of food and habitat use among fish assemblages of the lower Slave River system and examines the potential for trophic interactions among the component species. Finally, Chapter 3 (General Discussion) provides a synthesis of the major findings and interpretation of the relative roles of biotic and abiotic factors that influence the structure of fish assemblages in the lower Slave River system. Chapter 3 also discusses the significance of the findings in relation to concerns of northern residents and future management concerns for fishes in this system.

Productivity of large rivers

Primary Productivity

The two main sources of primary production in river systems can be divided into autochthonous (i.e., within-system) production and allochthonous (i.e., outside-system) inputs (Johnson *et al.* 1995). Autochthonous production is generally low in the mainstems of large rivers (Welcomme 1985; Barton 1986) due to factors such as high discharge and suspended sediment concentrations that cause high turbidity. The high turbidity, characteristic of large rivers, limits light penetration and thus aquatic plant growth (Welcomme 1985; Bodaly 1989; Johnson *et al.* 1995). Also, a strong, steady current hinders the establishment of aquatic macrophytes (Junk *et al.* 1989). Other factors limiting macrophyte establishment in large rivers are substrate type, nutrients and flooding (Hynes 1970; Keup 1988). Similarly, periphyton and phytoplankton production is generally limited by light penetration, water current and the substantial depth of most large rivers (Roy 1989). Phytoplankton production is minimal if current velocity is greater than 0.2 m sec^{-1} (Roy 1989 citing Tseeb 1962), which is often the case in the mainstems of large rivers. However, Barton (1986) found that although virtually no rooted aquatic plants existed in the Athabasca River, the algal flora was rich, particularly with diatoms and blue-green algae, in the summer months.

In contrast to the generally low levels of autochthonous production, allochthonous inputs are a substantial source of energy in large rivers (Barton and Lock 1979; Barton 1980; Barton 1986). In the Athabasca River, Barton (1980) reported the presence of large quantities of drifting coarse material, such as leaves, grasses and woody debris, particularly during periods of high water levels, and that these materials were frequently colonized by aquatic invertebrates. Allochthonous input from woody debris was also a main contributor in the Fraser River system (Northcote and Larkin 1989). Although studies on rivers such as the Missouri (Hesse *et al.* 1989) and Columbia (Ebel *et al.* 1989) find that most primary production is of autochthonous origin, this is primarily produced in the still-waters of reservoirs. Indeed, many temperate and sub-tropical river systems have had various degrees of modifications (Welcomme *et al.* 1989) such as diversions, reservoirs or impoundments, and thus are likely much different than free-flowing northern rivers.

Secondary Production

Many species of aquatic invertebrates often require particular habitats to thrive (Keup 1988). The distribution and abundance of aquatic invertebrates are generally influenced by characteristics of the substrate, such as particle size, stability, and heterogeneity (Hynes 1970; Minshall 1984; Keup 1988; Knight and Ross 1994). The velocity of water flow in a river determines the suspended sediment load and turbidity, the rate of sediment deposition, and substrate type (Ryder and Pesendorfer 1989), with the result being that limitations in standing stocks of aquatic invertebrates are often associated with high discharges and turbidities (Barton 1980; Ryder and Pesendorfer 1989).

Sand and mud-based riverbeds, which are typical of large rivers, are unstable and continuously shifting due to the overlying current; as a result, they are often unsuitable habitats for many aquatic invertebrates (Hynes 1970; Barton 1980, 1986; Angermeier 1985). Substrates such as sand, mud and silt also lack suitable interstitial spaces that are more common in the heterogeneous environments of cobble and gravel. Interstitial space provides attachment sites, protection from predators and the current, and food for aquatic invertebrates (Keup 1988). In the Athabasca River, Barton (1980) found that where unstable coarse sand was the predominant substrate, aquatic invertebrates were few and limited primarily to chironomids and oligochaetes, whereas the more stable substrates associated with bedrock supported a greater variety of aquatic invertebrates, including Ephemeroptera, Plecoptera, and Trichoptera (Barton 1980). Although the mainstems of large rivers generally have unsuitable substrate for aquatic invertebrates, drifting organic material, such as leaves, trees, and woody debris, provides attachment sites for filter feeders, as well as a source of food for shedders and scrapers (Barton 1980, 1986; Keup 1988).

A more diverse assemblage of aquatic invertebrates is often found in tributaries of large rivers. Tributaries are often much shallower, with reduced currents and turbidity, and often have flourishing aquatic vegetation, which provides more suitable habitats for many aquatic invertebrates. Benthic invertebrates such as gastropods and amphipods, which are generally absent in mainstems (Roy 1989), are often present within tributaries.

The abundance of zooplankton in most large rivers is also usually limited (Roy 1989). The source of zooplankton in rivers would generally be upstream lakes. Upon entering the river, zooplankton abundance would be heavily diluted as they are carried downstream. Exceptions of high zooplankton abundance in rivers are generally found in impounded systems, such as those of the Missouri (Hesse *et al.* 1989), Columbia (Ebel *et al.* 1989) and Colorado Rivers(Carlson and Muth 1989), where still-water reservoirs enable zooplankton to flourish. In these reservoirs, zooplankton are probably a main source of food for many fish, especially young-of-the-year (Hesse *et al.* 1989; Ebel *et al.* 1989).

Fish Productivity

Fish species diversity generally increases with stream order, however, in larger rivers with stream orders above four to six, species diversity may often plateau or even decrease (Horwitz 1978). As rivers increase in stream order, factors such as water temperature, river morphology, habitat diversity and low invertebrate abundance may limit fish species composition (Paller 1994). Because of low autochthonous productivity, invertebrate-feeding fish must often rely mainly on drifting invertebrates and terrestrial-based energy inputs, such as flying insects and detritus (Keup 1988). Also, there are often increased numbers of larger fish, particularly piscivores, in the downstream reaches (Keup 1988; Bayley and Petrere 1989; Novoa 1989; Paller 1994), which may also limit and shape fish species diversity and composition.

Since productivity in large rivers is generally low, many large rivers are used primarily as migration corridors, with relatively few species being resident. Extensive migrations to and from spawning destinations are common, as are migrations to overwintering grounds, and movements between lake environments (Bayley and Petrere 1989; Bodaly *et al.* 1989; Novoa 1989; Roy 1989).

Fish species diversity in northern systems is generally quite low in comparison with tropical and temperate river systems, when standardized on the basis of watershed area (Welcomme 1985; Bodaly *et al.* 1989). This difference is primarily due to increased climatic severity in northern regions, including shorter growing seasons and lower mean daily water temperatures (Morin *et al.* 1981; Bodaly *et al.* 1989), and to postglacial dispersion patterns (Morin *et al.* 1981; Lindsey and McPhail 1986).

The Study System: lower Slave River, Northwest Territories

The Slave River and its delta are part of the Mackenzie River System. The Slave River flows northward from the Peace-Athabasca Delta in northern Alberta to the Slave River Delta at Great Slave Lake in the Northwest Territories. This large river has a mud bottom, and steep, sandy cutbanks (Vanderburgh and Smith 1988). There are four sets of rapids over a distance of 29 km between Fitzgerald, Alberta to Fort Smith, NWT, creating a potential barrier to upstream-moving fish. From the Rapids of the Drowned at Fort Smith, NWT, the river flows steadily approximately 320 km to the Slave River Delta at Great Slave Lake.

The Slave River receives a significant proportion of its water and sediment loads from the Peace River. About 77% of the water flow in the Slave River during the spring originates from the Peace River, and during the fall, the Peace River contributes about 42% of the water flow (English *et al.* 1996). Since the construction of the W.A.C. Bennett Dam on the Peace River in late 1960's, the Slave River has experienced a 33%

(372, 491 t yr^{-1}) reduction in the average annual sediment load, affecting the growth and development of the Slave River Delta (English *et al.* 1996). In contrast, the Athabasca River Delta releases most of its sediment load into Lake Athabasca before continuing on into the Slave River (Brunskill 1986).

The lower Slave River near Fort Smith is a homogenous system, characterized by turbid, fast-flowing water and steep river banks with very little aquatic vegetation. At this location, the river has a maximum width of approximately 3 km, with the cut-bank levees reaching up to 35m high (Vanderburgh and Smith 1988).

The Slave River Delta enters Great Slave Lake midway along the south shore. There are four main channels that connect the Slave River to Great Slave Lake, plus many small channels, perched basins, and wetlands, creating very diverse habitat types, compared with the mainstem of the river. Shoreline habitat ranges from heavily vegetated shorelines on gently sloping banks to steeper banks with narrow littoral zones and little vegetation.

Very few active tributaries are located along the lower Slave River between the Territorial border at Fort Smith and the Slave River Delta at Great Slave Lake. The Salt River is the largest tributary of the Slave River, located 25 km downstream of Fort Smith. It is a very meandering and narrow river, compared with the Slave River, with a maximum width of about 60 m and an average maximum depth of 1 to 2 m. It also differs from the Slave River by the greater amounts of aquatic vegetation present in the summer and early fall.

Previous studies have documented up to 23 fish species in the Slave River and its delta (Tripp *et al.* 1981; McLeod *et al.* 1985). The most abundant larger-bodied fish include burbot (*Lota lota*), flathead chub (*Platygobio gracilis*), goldeye (*Hiodon alosoides*), inconnu (*Stenodus leucichthys*), lake whitefish (*Coregonus clupeaformis*), longnose sucker (*Catostomus catostomus*), northern pike (*Esox lucius*), and walleye (*Stizostedion vitreum*). Together, these species and others present in the Slave River make up a diverse fish assemblage.

The main objective of this study was to examine spatial and temporal patterns of food and habitat use among fish assemblages of the lower Slave River system and to examine the potential for trophic interactions among the component species. Since systems in the north are highly variable and are often of low productivity, fishes must be adaptable to different physical and biotic conditions. My expectation was that most of these study fishes would exhibit a generalist strategy with respect to food and habitat use within the Slave River system. Understanding the principal roles of biotic and abiotic factors structuring fish assemblages in this system should aid in future management decisions as industrial activities continue to develop upstream and along the Slave River.

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Chapter 2. FOOD AND HABITAT USE WITHIN THE FISH ASSEMBLAGES OF THE LOWER SLAVE RIVER, NORTHWEST TERRITORIES

Introduction

Identifying spatial and temporal patterns of food and habitat use is important in understanding ecological relationships among species (Keast 1978; Johnson and Dropkin 1993). Coexisting organisms may interact through the shared use of resources such as food and habitat, which may have a major influence on population and community structure (Schoener 1974; Ross 1986). Abiotic conditions such as physical harshness and disturbance may also influence community structure (Magalhaes 1993). In the past there has been much controversy over the relative roles of biotic versus abiotic factors influencing the structure of fish assemblages (Schlosser 1987). However, it is now widely recognized that both kinds of factors act together in structuring communities (Sousa 1984; McNeely 1987; Schlosser 1987; Magalhaes 1993; Magnan *et al.* 1994).

Investigations into the processes structuring fish assemblages in flowing waters have largely focused on small and medium-sized temperate streams (e.g., Angermeier and Karr 1983; Meffe and Sheldon 1988) with few comparable studies on larger streams and rivers (Lobb and Orth 1991). These studies of stream fish assemblages often find that food and habitat are important factors interacting to structure fish assemblages (Baker and Ross 1981; Paine *et al.* 1982; Ross 1986; McNeely 1987; Glova and Sagar 1991; Magalhaes 1993). Often, differences in the use of these resources among the fishes of an assemblage are observed, which may act to reduce inter- and/or intra-specific competition. Differential use of food resources, which is often linked with differences in mouth characteristics (Keast 1978, 1985; Magalhaes 1993), can be observed as seasonal (Angermeier 1982, 1985; Greger and Deacon 1988; Magalhaes 1993), and/or diel differences in diet (Glova and Sagar 1991). Differential use of habitat in stream fish assemblages has been attributed to various factors, including current (Gorman and Karr 1978; Schlosser 1982; Moyle and Vondracek 1985; Glova and Sagar 1991), depth (Gorman and Karr 1978; Baker and Ross 1981; Schlosser 1982; Moyle and Vondracek

1985), occurrence of aquatic vegetation (Baker and Ross 1981), and substrate type (Paine *et al*. 1982; Schlosser 1982).

However, many differences exist between streams and large rivers, particularly between temperate streams and large northern rivers (Chapter 1). Because of these differences, and the differential use of resources among species, the relative importance of biotic and abiotic factors may differ to various degrees in large river fish assemblages compared with the better studied stream fish assemblages. Since few integrative studies have been conducted on resource use of fishes in large northern rivers, there is a real need to quantify these patterns, so we can have a better understanding of the relative roles that biotic and abiotic factors play in structuring fish assemblages in large northern rivers.

The Slave River of northern Alberta and the Northwest Territories, Canada, is a relatively pristine large northern river in the Mackenzie River Basin, providing important traditional fishing grounds for aboriginal subsistence and commercial fisheries (Bodden 1980). However, as industrial activities expand on the Peace and Athabasca Rivers upstream of the Slave River, there is increased concern from northern residents about the quality of water and fish resources in this system. Since very few studies have previously been conducted on the Slave River, it is important to examine seasonal variations in the use of food and habitat of fish assemblages in the Slave River system to have a better understanding of the potential pathways that contaminants bio-magnify within the food web and how physical alterations to the Slave River (i.e., construction of dams) may alter fish assemblage structure.

The objectives of my study were to quantify spatial and temporal patterns of food and habitat use among fish assemblages of the lower Slave River system and to examine the potential for trophic interactions among the component species.

Materials and Methods

Study Area

The Slave River is, by far, the largest tributary into Great Slave Lake (Figure 2-1); in the Northwest Territories, the Slave River basin drains an area of 2,252 km^2. From the Rapids of the Drowned at Fort Smith, NWT (60°00'N, 111°53'W), the river flows

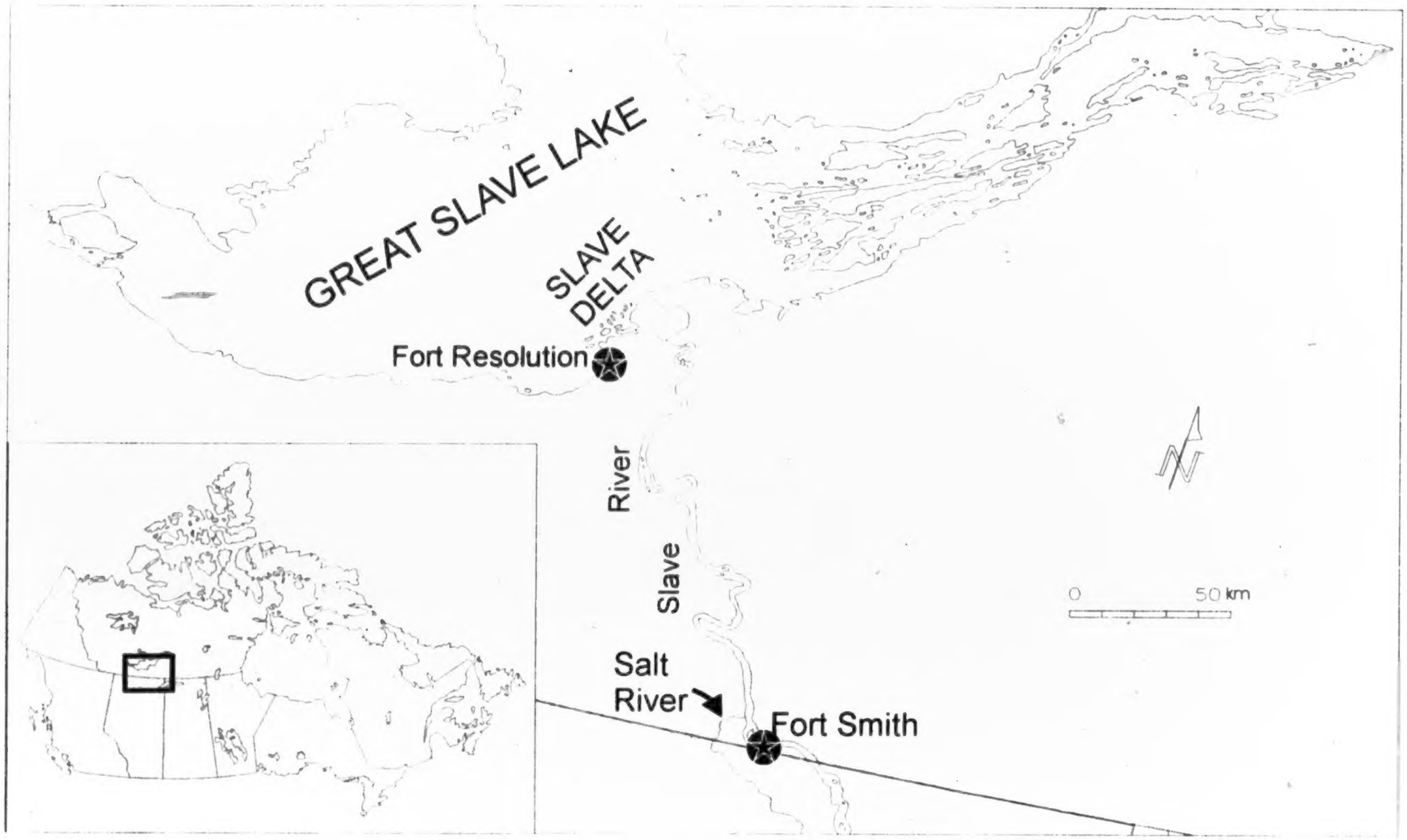

GREAT SLAVE LAKE
SLAVE DELTA
Fort Resolution
River
Slave
Salt River
Fort Smith
N
0
50 km

Figure 2-1. Geographical location of the Slave River, Salt River, and Slave Delta sampling areas on the lower Slave River system, Northwest Territories (modified from Tallman et al. 1996).

approximately 320 km to the Slave River Delta at Great Slave Lake. Three study areas were chosen for comparison: 1) the Slave River Delta, 2) the Slave River, immediately downstream of the Rapids of the Drowned near Fort Smith, NWT and 3) the lower Salt River.

The Slave River Delta is located midway along the south shore of Great Slave Lake, approximately 13 km north-east of Fort Resolution (61°10'N, 113°40'W), where it covers an area of approximately 78 km^2 (English 1979). The delta is represented by very diverse habitat types, compared with the main stem river proper, as a result of the numerous and variously sized channels. Landforms range from large mud flats on the outer edges of the Delta, to cut-bank levees ranging in height up to 3 m (English 1979). Shoreline habitat ranges from heavily vegetated shorelines on gently sloping banks to steeper banks with narrow littoral zones and little vegetation. The dominant submergent macrophytes are *Potomogeton pectinatus*, *P. richardsoni*, and *P. gramineus*, and the dominant emergent aquatic macrophytes are *Equisetum fluviatale* (horsetails) and *Typha latifolia* (cattails) (Tripp *et al.* 1981).

The delta includes four main channels that connect the Slave River to Great Slave Lake: 1) ResDelta, 2) East Channel, 3) Middle Channel, and 4) Old Steamboat Channel (Figure 2-2). ResDelta Channel is the largest channel through the delta, accounting for 86% of the water flow (Tripp *et al.* 1981), with maximum depths ranging from 12 to 32 m (Tripp *et al.* 1981; per. obs). The other main channels ranged from 5 to 12 m deep. Most delta sampling occurred along these main channels. The Slave River Delta also contains numerous minor channels (Figure 2-2), with depths of 1 to 2 m.

The lower Slave River near Fort Smith (Figure 2-3) is a more homogenous system, characterized by turbid, fast flowing water and steep river banks, both of which deter aquatic plant establishment within the narrow littoral zone. At this location, the river has a maximum width of approximately 3 km (Vanderburgh and Smith, 1988), with the cut-bank levees reaching up to 35 m high (Vanderburgh and Smith 1988).

The Salt River is the largest tributary of the Slave River, entering the latter 25 km downstream of Fort Smith (Figure 2-4). However, it is a very meandering and narrow river, compared with the Slave River, with a maximum width of about 60 m and an

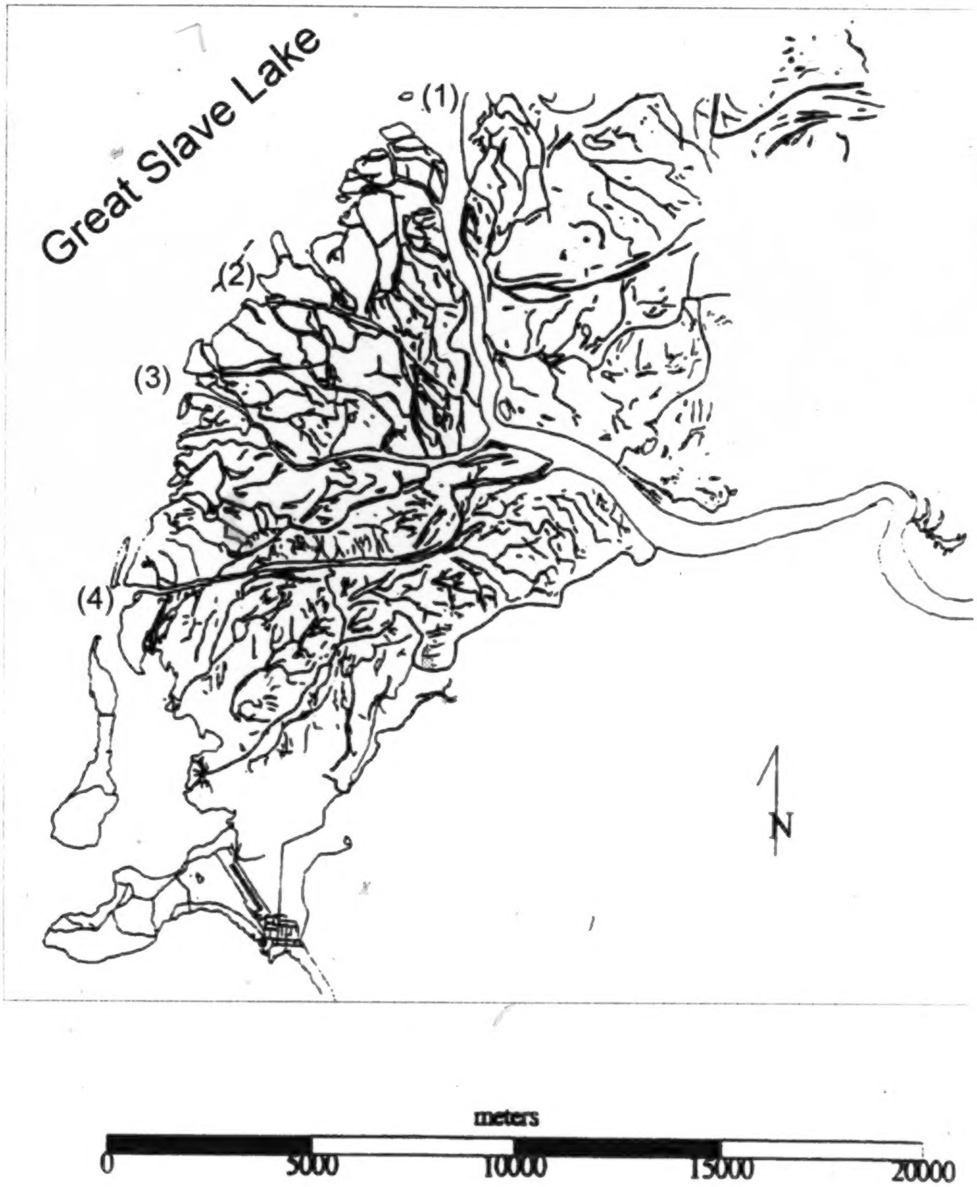

Great Slave Lake
(1)
(2)
(3)
(4)
N
meters
0
5000
10000
15000
20000

Figure 2-2. Map of the Slave River Delta (modified from English et al. 1996), where (1)=ResDelta Channel, (2)=East Channel, (3)=Middle Channel, and (4)=Old Steamboat Channel. See Appendix A for exact sampling locations.

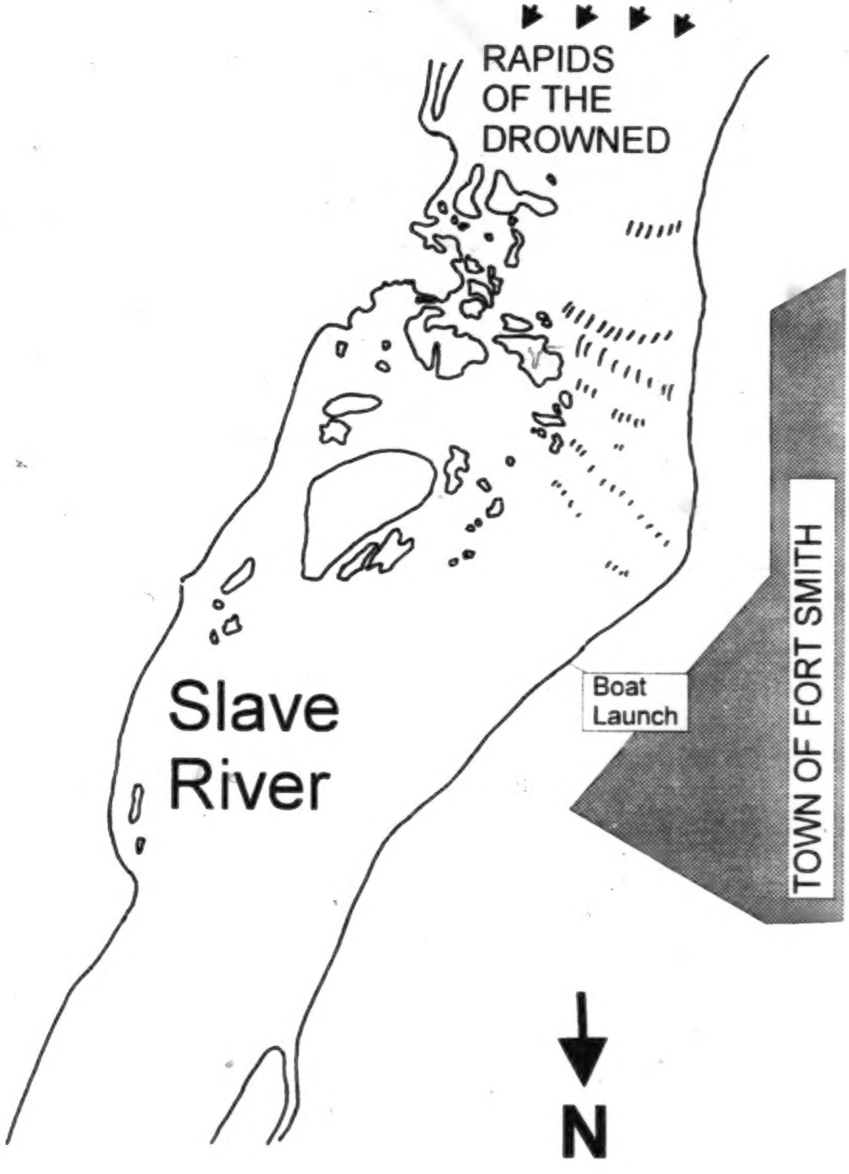

RAPIDS OF THE DROWNED
Boat Launch
Slave River
TOWN OF FORT SMITH
N

Figure 2-3. Map of the Slave River at Fort Smith, Northwest Territories (modified from Tallman et al. 1996). See Appendix B for exact sampling locations.

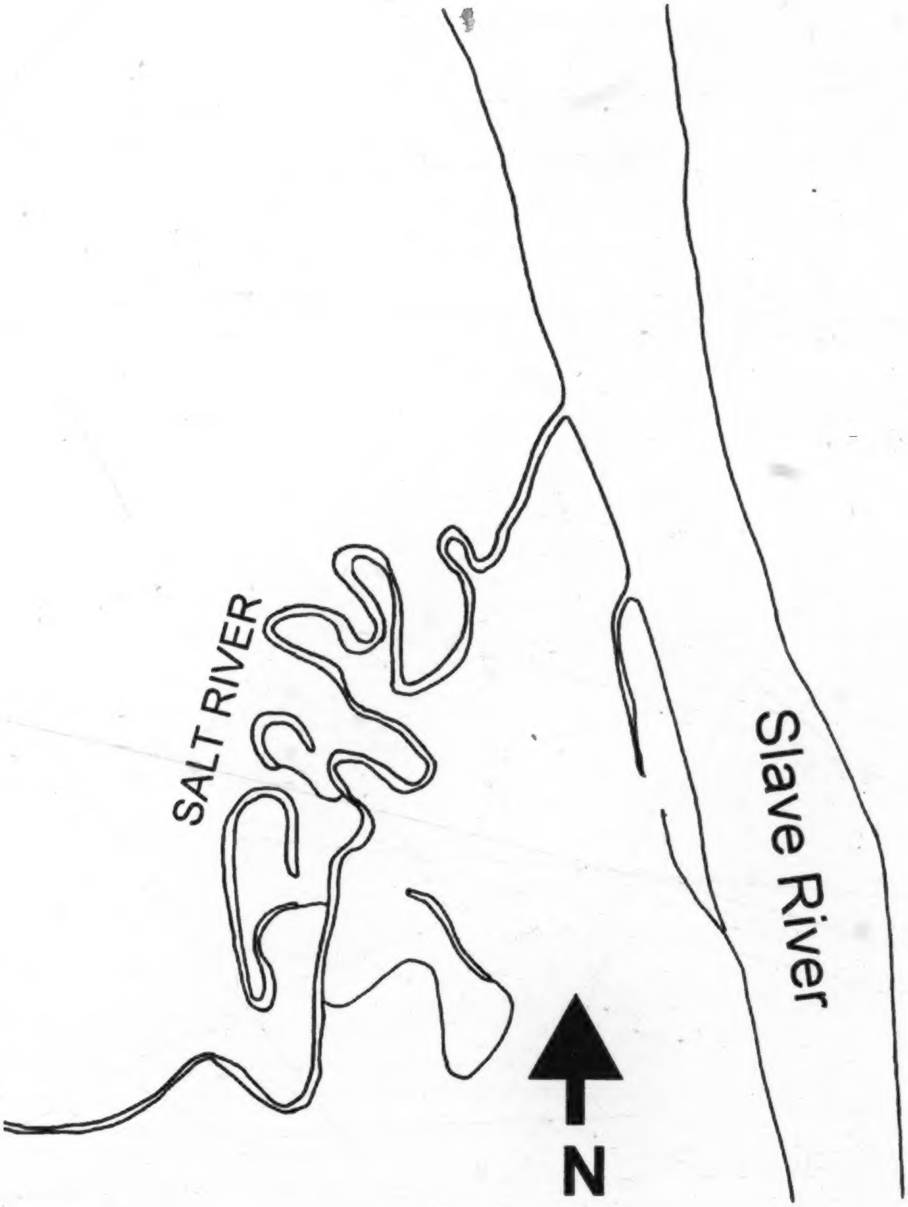

SALT RIVER
Slave River
N

Figure 2-4. Map of the lower Salt River (modified from Tallman et al. 1996). See Appendix C for exact sampling locations.

average maximum depth of 1 to 2 m. It also differs from the Slave River by the greater amounts of aquatic vegetation present, dominated by *Potomogeton* sp., and *Ceratophyllum* sp.

Field Procedures

Fish were collected during the open-water period every 2 to 4 wk from the three study areas in 1994 (July to August) and 1995 (May to August and October).

To reduce effects of gear selectivity on species and sizes of fish caught, fish were collected using various sampling techniques. Collecting methods included: (1) two types of experimental (multi-mesh) gillnets, 1.8 m deep, each made up of three 10m panels of different meshes (38, 51 and 63.5 mm; and 76, 89 and 102 mm stretched mesh), (2) single-mesh gillnets, 25 m in length, 1.8 m and 2.4 m deep, and either 114 mm or 133 mm stretched mesh (3) a 16.8 m beach seine, 1.2 m deep with a 5 mm stretched mesh and (4) set lines. Set lines are more effective in catching piscivorous fish, such as burbot, that live mainly at the bottom of the river; due to the strong current, gillnets set at the river bottom would be buried by bottom sediments. Upstream beach seine sweeps were used to capture small fish near shore, such as minnows and young-of-the-year fish, which were too small to be captured by gillnet. However, the primary fish collection method was gillnets set in backeddies. Gillnets were mostly set for 3- to 4-h periods.

The following biological data were taken from individual fish: fork and standard lengths (mm) and total mass (g) were measured, sex and stage of maturity was recorded, and aging structures (scales, pectoral fin rays, and otoliths) were collected. For the analysis of diet, the complete digestive tract, from the oesophagus to the anus, was removed and frozen within 3 h after capture.

To determine patterns of habitat use within the fish assemblages of the three study areas, I quantified habitat characteristics at all of the locations where gillnets were set. At the time that each net was checked, I measured the following habitat variables: distance from shore, water flow direction in the back-eddies, water temperature, presence or absence of vegetation and general weather conditions. As well, water current readings were measured bi-weekly at commonly used gillnetting stations using a magnetic flow meter. River discharge rates and continuous water temperatures were obtained from Water Survey Canada, Fort Smith, NWT. The amount of vegetation at each gillnet station was determined monthly using three randomly-placed 1 x 1 m quadrats; the coverage of aquatic vegetation within each plot was visually scored on a scale from 0 (absence) to 10 (100% coverage).

Determination of Catch-Per-Unit-Effort (CPUE)

Catch-per-unit-effort (CPUE) was calculated for nets set every 2 wk for the Slave River and its delta in 1994 and 1995 combined, and for the Salt River in 1995. Net length was standardized to 30m, e.g., the catch for a 25m net was multiplied by 30/25 to convert to 30m. Net depth was standardized in the same manner to a 2 m deep net. The CPUE was calculated for each set by dividing the standardized catch for that set by the soak time (in hours).

Habitat Analysis

To analyze the overall patterns of habitat use by species in the fish assemblages among the three study locations (regional differences), I conducted a Principal Components Analysis (PCA) on a weighted mean of species/location-by-habitat variable matrix. Principal Components Analysis summarizes the multidimensional species' population-by-habitat variables matrix in fewer dimensions, with the goal of producing a small number of interpretable axes. For each of the three study locations, a weighted mean of each habitat variable was calculated for each species, i.e., for each individual fish caught, a value for each of the five habitat variables could be assigned, and a species' average for these five variables was calculated for each of the three locations to be used in the data matrix (habitat variables as columns and species per location as rows). In the resulting ordination, species' populations characterized by similar values of the habitats variable will be positioned close to each other, whereas species populations characterized by quite disparate habitat values will be located far apart. Each habitat variable is represented in the PCA biplot as an arrow; the direction of the arrow indicates the direction of increasing values for that variable and the length of the arrow indicates the relative rate of increase in that direction. The amount of variation explained by each axis is measured by its eigenvalue. Eigenvalues of PCA all lie between 0 and 1, and typically only the axes with the largest eigenvalues display the biologically relevant information (Ter Braak 1987a). PCA was carried out using the CANOCO computer program (Ter Braak 1987b).

The association of individual species in each location to the five specific habitat variables were analyzed using two methods. First, Pearson's Coefficients of Correlation were calculated between the five habitat variables and CPUE of each species from every net set, including those nets in which a species was absent; secondly, PCA, similar to the one described above, was performed for each of the locations separately. The difference between these two analyses is that PCA compares the habitat scores for each species with all other species-habitat scores within the particular assemblage, whereas, the correlation analysis compares a specific species with a specific habitat variable.

Diet Analysis

In the laboratory, stomach contents were sorted into taxonomic categories, weighed and measured. Blotted wet mass, maximum lengths (for fish prey in most cases, this represented total length), and maximum body depths were measured for fish prey items. The frequency of occurrence, and the percentage composition of prey taxa by number and by mass of all prey taxa were calculated for each fish species to estimate the relative importance of those food taxa in a species' diet (Hyslop 1980). The Relative Importance Index, RI (George and Hadley 1979), is essentially a mean of the three diet measures for each prey taxa (Wallace 1981). For a given fish species, the Relative Importance of prey taxon *i* is calculated as:

$$RI_i = 100\, AI_i / \sum_{i=1}^{n} AI_i$$

where AI_i = the absolute importance of prey taxon *i*,

= % frequency of occurrence + % total numbers + % total mass;

n = the number of different food types;

% frequency of occurrence = the percentage of all stomachs containing food in which prey taxon *i* occurred,

% total numbers = the percentage that items of prey taxon *i* contributed to the total number of food items in all stomachs, and

% total mass = the percentage that the mass of prey taxon *i* contributed to the total mass of food in the stomach

This index of Relative Importance was modified for species consuming plant material, and detritus since it is impossible to calculate the percentage composition by total number for these food categories. Thus, the calculation for the index of Relative Importance for these food categories was as follows:

$$RI_i = 100\, AI_i / \sum_{i=1}^{n} AI_i, \text{ where,}$$

AI_i = % frequency occurrence + % total mass

For stomach contents containing only digested remains of fish prey, diagnostic hard structures, such as otoliths and pharyngeal arches, were used to identify ingested prey items where possible. Prey identified by hard structures were not included in the RI calculations since the mass of the prey would have been grossly underestimated.

Food relationships between species in each study area were analyzed using two methods.
(1) The pair-wise dietary overlap index of Schoener (1974):

$$\alpha_{xy} = 1 - 0.5 \left(\sum_{i=1}^{n} | p_{xi} - p_{yi} |\right)$$

where α_{xy} = the overlap between species *y* and species *x*;

p_{yi} = the proportion of food taxon *i* in the diet of species *y;*

p_{xi} = the proportion of food taxon *i* in the diet of species *x;*

n = the total number of prey taxa shared between *x* and *y*.

The index ranges from 0 (no overlap) to 1 (complete overlap); an index value of 0.3 or less indicates little overlap in the diets, whereas an index value of 0.7 or more indicates a high degree of overlap (Keast 1978). The Indices of Relative Importance (RI) calculated for each prey taxon were the values used as the proportion of each taxon required for Schoener's overlap index.

(2) Multivariate Ordination:

The multivariate ordination technique, Detrended Correspondence Analysis (DCA) was used to complement results from the analysis of pairwise overlap. Detrended Correspondence Analysis summarizes the multidimensional predator-by-prey matrix in fewer dimensions. This ordination technique was designed specifically for discrete data and is very effective for community-level dietary analysis by producing a small number of interpretable axes (Graham and Vrijenhoek 1988). In this study, the data matrix consisted of prey categories as columns and fish predators per season as rows. Values assigned to individual prey categories within the data matrix were based on the calculated Relative Importance (George and Hadley 1979) of each prey category. Predator per season scores (represented by eigenvectors) with similar diets are positioned close to each other, whereas scores far apart represent predator per season combinations with dissimilar diets. The amount of variation explained by each axis is measured by its eigenvalue. Eigenvalues of DCA all lie between 0 and 1, and typically only the axes with the largest eigenvalues display the biologically relevant information (Ter Braak 1987a). DCA was carried out using the CANOCO computer program (Ter Braak 1987b).

Results

Fish Species Composition

Overall, 23 fish species were documented at the three sampling locations (Table 2-1). Cisco, lake chub, trout-perch, ninespine stickleback, emerald shiner, spottail shiner, and spoonhead sculpin were other species caught in beach seines but were not included in the diet and habitat analyses.

Fish species composition was relatively similar throughout all study areas, with the following exceptions: white suckers were present only in the Salt River; inconnu were present only in the Slave River and its delta; cisco and lake chub were present only in the Slave River Delta.

Table 2-1. List of scientific names, common names, codes, and locations for fish species collected in the lower Slave River system, 1994 to 1995, and the presence of species from previous studies (1972-1985).

					Presence of Species from Previous Studies		
Species Name	Common Name	Code	Location (present study)	Little (1996)	Tripp *et al.* (1981)	McLeod *et al.* (1985)	Nelson and Paetz (1972)
Catostomus catostomus[1]	longnose sucker	LNSK	Slave/Delta/Salt	X	X	X	X
Catostomus commersoni[1]	white sucker	WTSK	Salt	X	X	X	X
Coregonus sardinella[2]	least cisco		Slave	X			
Coregonus artedi[2]	cisco	LKSC	Slave/Delta	X	X	X	
Coregonus clupeaformis[1]	lake whitefish	LKWT	Slave/Delta/Salt	X	X	X	
Cottus cognatus	slimy sculpin				X	X	
Cottus ricei	spoonhead sculpin	SPSC	Slave/Delta/Salt	X	X	X	X
Couesius plumbeus	lake chub	LKCB	Delta	X	X	X	
Culaea inconstans	brook stickleback						X
Esox lucius[1]	northern pike	NTPK	Slave/Delta/Salt	X	X	X	X
Hiodon alosoides[1]	goldeye	GOLD	Slave/Delta/Salt	X	X	X	
Lampetra japonica	Arctic lamprey	ARLP	Slave/ Delta	X	X	X	
Lota lota[1]	burbot	BRBT	Slave/Delta/Salt	X	X	X	
Notropis atherinoides	emerald shiner	EMSH	Slave/Delta/Salt	X	X	X	
Notropis hudsonius	spottail shiner	SPSH	Slave/Delta/Salt	X	X	X	
Oncoryhnchus keta	chum salmon				X	X	
Oncoryhnchus mykiss[2]	rainbow trout		Slave	X		X	
Oncorhynchus nerka[2]	sockeye salmon		Slave	X			
Oncoryhnchus tshawytscha[2]	chinook salmon		Slave	X			
Perca flavescens[1]	yellow perch	YWPH	Slave/Delta	X	X	X	
Percopsis omiscomaycus	trout-perch	TRPH	Slave/Delta/Salt	X	X	X	

Table 2-1. Continued:

Species Name	Common Name	Code	Location (present study)	Presence of Species from Previous Studies			
				Little (1996)	Tripp *et al.* (1981)	McLeod *et al.* (1985)	Nelson and Paetz (1972)
Platygobio gracilis[1]	flathead chub	FHCB	Slave/Delta/Salt	X	X	X	
Prosopium cylindraceum	round whitefish				X	X	
Pungitius pungitius	ninespine stickleback	NSST	Slave/Delta/Salt	X	X	X	X
Salvelinus namaycush[2]	lake trout	LKTR	Delta	X		X	
Semotilus margarita	pearl dace				X	X	
Stenodus leucichthys[1]	inconnu	INCO	Slave/Delta	X	X	X	
Stizostedion vitreum[1]	walleye	WALL	Slave/Delta/Salt	X	X	X	X
Thymallus arcticus	Arctic grayling				X	X	

[1] Study species
[2] Rare species caught in present study

Seasonal variation in the abundance of fishes caught in the Slave and Salt Rivers was evident throughout the 1994 and 1995 sampling periods (Figure 2-5 and 2-6, respectively). For the Slave River and Delta, the CPUE was combined for 1994 and 1995 data, since similar results were evident. Two main groups can be identified in the Slave River, resident species and migratory species. Resident species are those that complete their life cycle within the river and its tributaries whereas migratory species spend only part of their life cycle in the river. Therefore, resident species included northern pike, walleye and goldeye. These species were generally found at higher numbers than other species throughout the entire open-water period (Figure 2-5). These aforementioned species were also resident in the Salt River, along with juvenile lake whitefish and white suckers (Figure 2-6). Also categorized as resident species were resident aggregate spawners such as flathead chub, longnose sucker and burbot. Flathead chub and longnose sucker were present within the Slave River throughout the entire open-water period but were found in highest abundance during the spring and early summer, with fewer numbers captured during the remainder of the sampling periods. Burbot were primarily found in congregations in December under the ice. In contrast to residents, migratory species included sexually mature inconnu and lake whitefish, which were present in the system mainly during their spawning migrations from Great Slave Lake in the late summer and fall (Figure 2-5).

Regional Differences in Habitat Use

Principal Components Analysis (PCA) performed on the species populations-by-habitat variables matrix separated the data matrix into the three regional fish assemblages: the Slave River near Fort Smith, the Salt River and the Slave River Delta (Figure 2-7). The first two axes accounted for 96% and 3% of the variance. Discharge was the most important variable along axis I, separating the populations in the low discharge Salt River from those in the other two locations, whereas aquatic vegetation was the most important variable along axis II. The Slave Delta fish assemblage was most closely associated with aquatic vegetation. The Slave River fish assemblage was most closely associated with higher currents, greater distances from shore and lower water temperatures.

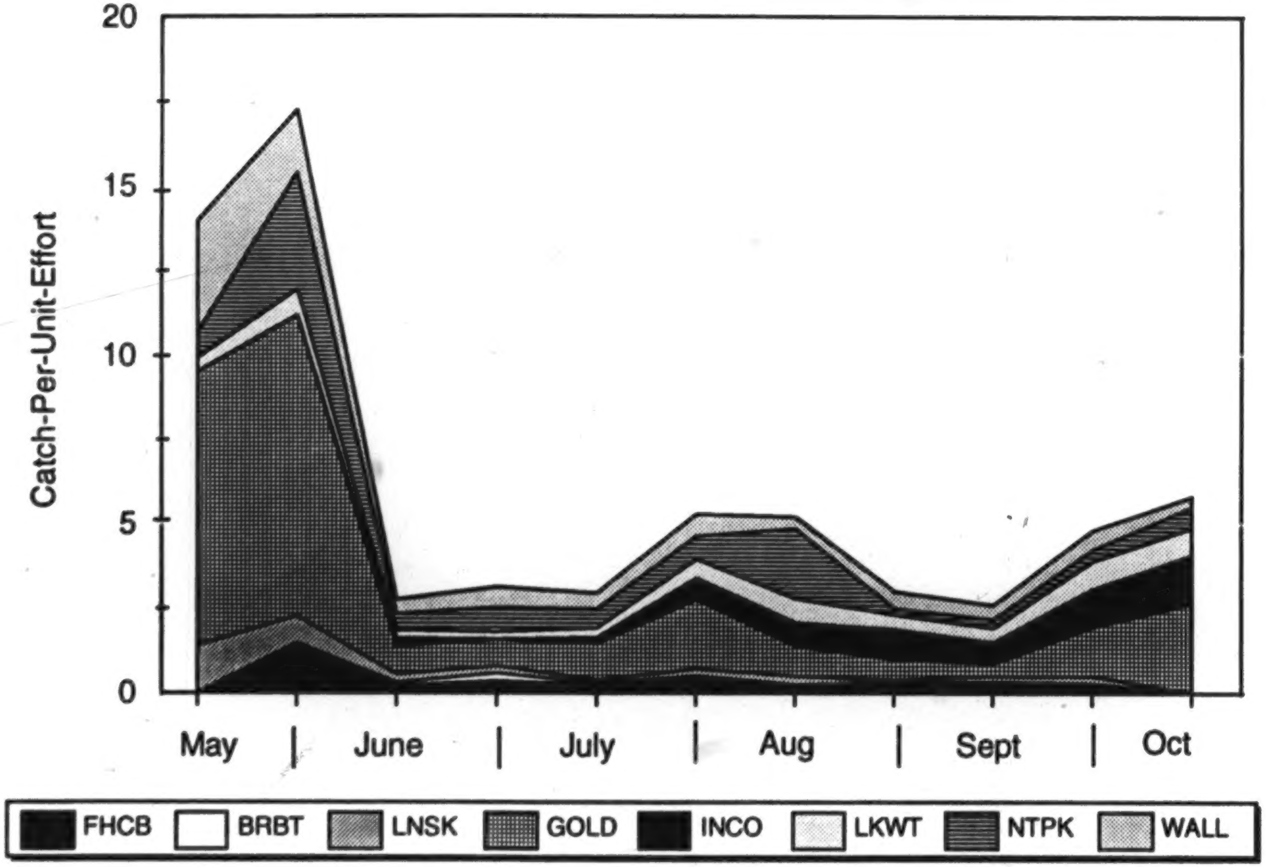


Figure 2-5. **Seasonal trends of the relative abundance (Catch-Per-Unit-Effort) of fishes in the Slave River and the Delta during 1994 (July to October) and 1995 (May to October).**

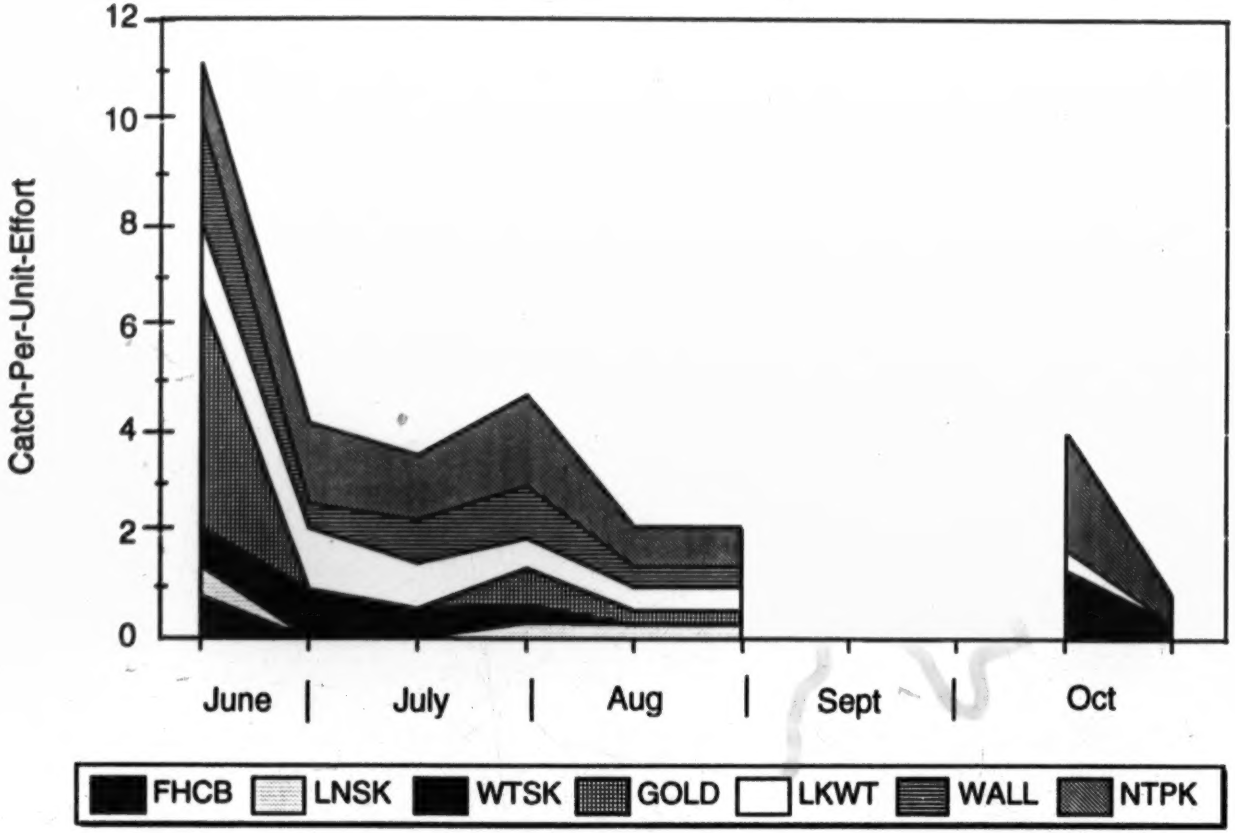


Figure 2-6. Seasonal trends of the relative abundance (Catch-Per-Unit-Effort) of fishes in the Salt River, from June to August, and October, 1995.

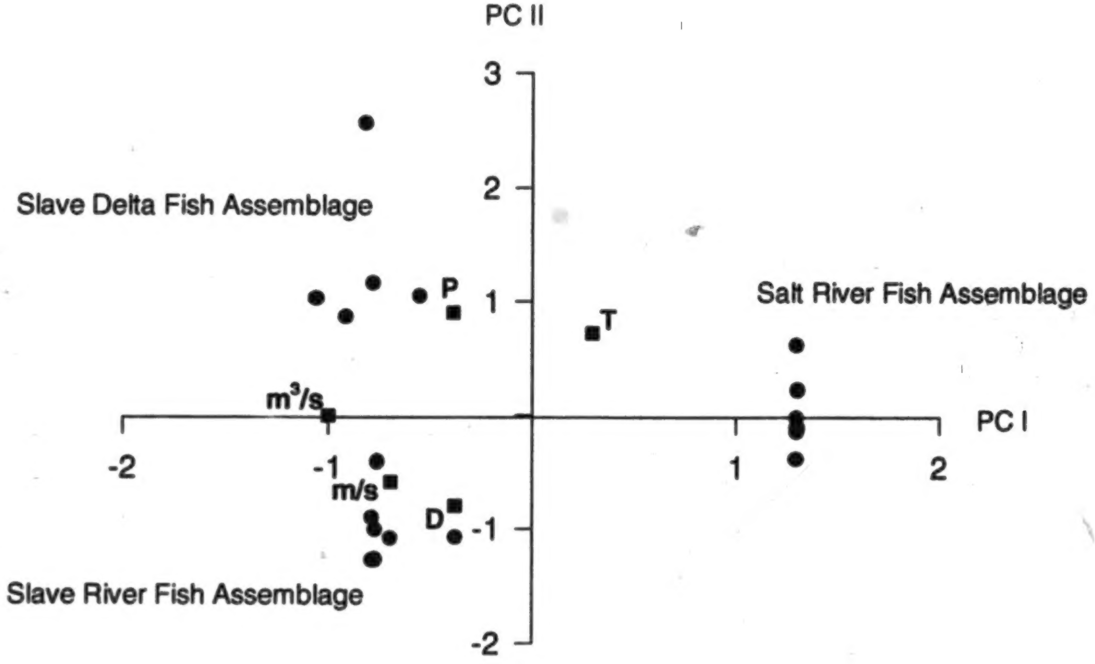


Figure 2-7. Principal Component Analysis on the fish species populations-by-habitat variables in the Slave River system in 1995, where T=water temperature, P=aquatic vegetation, m^3/s=discharge, m/s=current, and D=distance from shore.

Local Variation in Habitat Use

Species-specific differences in habitat use were evident in the three PCAs from each of the three study areas.

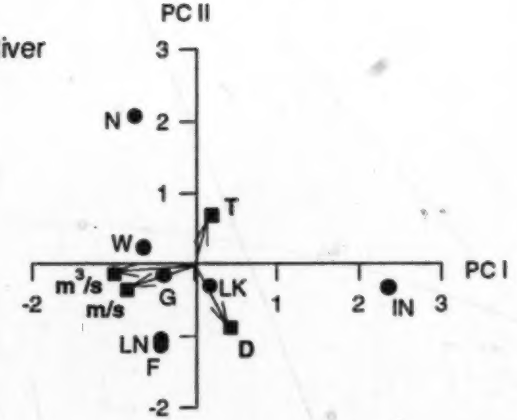
For the Slave River fish assemblage, the first principal component, which explained 70% of the variation, was most strongly associated with discharge and current (Figure 2-8a). The second principal component, with an eigenvalue of 25%, was related most strongly and negatively to distance from shore, and positively to temperature. The widely separated species scores indicated that most of the fishes of this assemblage differed in their degree of association with the measured habitat variables. The exceptions were flathead chub and longnose suckers, which were both more strongly associated with lower water temperatures than the rest of the Slave River assemblage and also occurred at relatively greater distances from shore. Walleye and goldeye were associated with moderate temperatures and moderate distances from shore, but higher discharge and current. Lake whitefish were only weakly associated with lower discharge, current and water temperature and greater distances from shore. The most distinct patterns of habitat use were displayed by inconnu and northern pike. Inconnu were associated with low discharge, and current, whereas northern pike were associated with inshore distances and warm water temperatures.

Correlation analysis of the habitat variables with CPUE showed relatively similar results to the PCA (Table 2-2). Northern pike had a negative correlation ($P<0.05$) with greater distances from shore, whereas flathead chub, lake whitefish and longnose suckers had a positive correlation ($P<0.001$). Flathead chub, longnose suckers, walleye ($P<0.001$), and goldeye ($P<0.05$) were negatively correlated with water temperature. Inconnu was the only species that had a negative correlation with discharge ($P<0.001$). No species exhibited significant correlations with current.

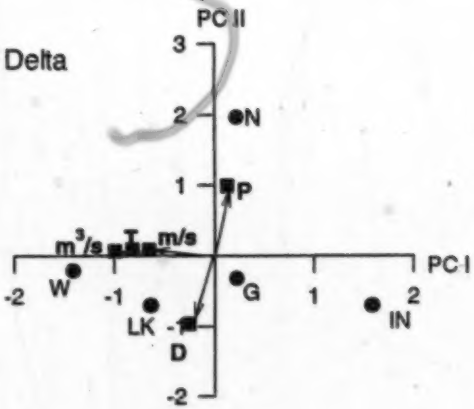
For the Slave Delta fish assemblage, the first principal component, which explained 69% of the variation, was most strongly associated with discharge and temperature (Figure 2-8b). The second principal component, with an eigenvalue of 30%, was related most strongly and positively to vegetation, and negatively to distance from shore. The

Figure 2-8. Principal Component Analysis on the fish species populations-by-habitat variables in the (a) Slave River, (b) Slave Delta, and (c) Salt River, in 1995, where T=water temperature, P=aquatic vegetation, m^3/s=discharge, m/s=current, and D=distance from shore; N=northern pike, W=walleye, IN=inconnu, G=goldeye, LK=lake whitefish, LN=longnose sucker, WT=white sucker, and F=flathead chub.

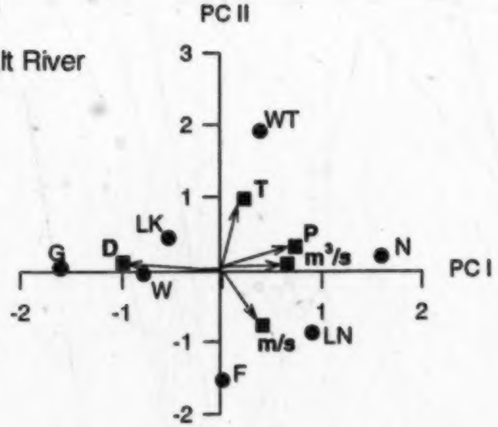
(a)
Slave River



(b)
Slave Delta



(c)
Salt River



widely separated species scores indicated that most of the fishes of this assemblage differed in their degree of association with the measured habitat variables. Northern pike was most strongly associated with higher amounts of aquatic vegetation and inshore distances, whereas lake whitefish were associated with little aquatic vegetation and greater distances from shore. Walleye were associated with increased discharge, temperature and current, whereas inconnu was negatively associated with these variables. Goldeye showed weak relations with all 5 habitat variables as its score was positioned close to the origin.

For the Correlation analysis (Table 2-2), northern pike were positively correlated ($P<0.05$) to aquatic vegetation, and negatively correlated to greater distances from shore ($P<0.05$). Inconnu were negatively correlated to aquatic vegetation, discharge and water temperature ($P<0.10$, $P<0.05$, $P<0.02$, respectively). Goldeye were negatively correlated with current ($P<0.10$), and walleye were positively correlated with discharge ($P<0.01$). Lake whitefish were not correlated to any of the habitat variables measured.

For the Salt River fish assemblage, the first principal component, which explained 77% of the variation, was most strongly and negatively associated with distance from shore (Figure 2-8c). The second principal component, with an eigenvalue of 19%, was related most strongly and positively to temperature. The widely separated species scores indicated that most of the fishes of this assemblage differed in their degree of association with the measured habitat variables. Northern pike were most closely associated with higher amounts of vegetation, greater discharge and more inshore distances. Walleye, goldeye and lake whitefish were associated with offshore distances, smaller discharges and little vegetation. Longnose suckers were most commonly associated with higher currents and white suckers with warmer temperatures.

Correlation analysis indicated that goldeye, walleye and lake whitefish catches were negatively correlated with aquatic vegetation and discharge, and positively to distance from shore (Table 2-2). Northern pike and white suckers were the only species positively correlated with temperature ($P<0.10$ and $P<0.002$, respectively), and longnose suckers and flathead chub were the only species negatively correlated to distance from shore ($P<0.05$, $P<0.001$).

Table 2-2. Correlations between fish catch-per-unit-effort and habitat variables for fishes in the lower Slave River, Northwest Territories, from May to August, 1995, where n is the number of total net sets at each of the study areas. Vegetation was absent at all Slave River sampling locations.

		d.f. (n-2)	Vegetation (0-10)	Distance from shore (m)	Current (m/s)	Discharge (m^3/s)	Temperature (°C)
Slave River	FHCB	52		**0.5976*****	0.1954	0.0812	**-0.4830*****
	GOLD	52		0.0645	0.0921	0.1811	**-0.2716***
	INCO	52		-0.0752	-0.2043	**-0.5295*****	-0.0443
	LKWT	52		**0.5173*****	-0.0715	-0.0798	-0.1268
	LNSK	52		**0.6550*****	-0.0164	0.0203	**-0.5749*****
	NTPK	52		**-0.2875***	-0.2221	-0.0523	0.0183
	WALL	52		0.0067	0.1540	0.1912	**-0.5190*****
Salt River	FHCB	39	-0.1980	**-0.3487***	0.0190	-0.2467	-0.1549
	GOLD	39	**-0.3540***	**0.3826***	-0.1856	**-0.4108****	-0.0896
	LKWT	39	**-0.3174***	**0.2960***	**-0.4319****	**-0.4792*****	0.1165
	LNSK	39	-0.1458	**-0.5716*****	-0.0530	-0.1064	-0.0963
	NTPK	39	-0.1007	-0.1914	-0.1961	0.1102	**0.2821***
	WALL	39	**-0.3409***	**0.2707***	**-0.4620****	**-0.4239****	-0.1138
	WTSK	39	-0.2498	-0.1208	**-0.3117***	-0.1872	**0.4866*****
Slave Delta	GOLD	30	-0.0433	-0.0382	**-0.3406***	-0.0348	0.1285
	INCO	30	**-0.3218***	-0.1070	-0.1356	**-0.3781***	**-0.4340***
	LKWT	30	-0.2484	0.0792	0.0193	0.1183	0.2751
	NTPK	30	**0.3850***	**-0.3651***	-0.1228	0.0798	0.2905
	WALL	30	-0.0959	-0.0843	-0.0750	**0.4766****	0.2136

* $P<0.10$
** $P<0.01$
*** $P<0.002$

The diets of resident and migratory piscivores

Northern Pike (*Esox lucius*)

Stomach contents were determined for northern pike from July and August in 1994 (n=90) and May to August and October in 1995 (n=322). A high percentage of fish had empty stomachs in both 1994 and 1995, comprising 65% and 68% of the samples respectively.

During 1994, 11 different prey taxa were found; 8 fish species (93% RI), 2 aquatic invertebrate orders (4%) and 1 terrestrial vertebrate taxon (2%)(Table 2-3). The most common prey found in the stomachs were northern pike and lake whitefish.

In 1995, 22 different prey taxa were documented (Table 2-3). Prey included 15 fish species (89% Relative Importance (RI), 4 invertebrate orders (7%) and 3 terrestrial vertebrate taxa (4%). The most dominant prey were burbot, flathead chub and suckers.

Diet in Different Habitats

For 1995, the data were divided into the three main sampling locations: the lower Slave River at Fort Smith, the Salt River and the Slave Delta (Figure 2-9). Prey diversity was highest in the Salt River (16 prey taxa), followed by 12 taxa in the Slave River and 9 in the Slave Delta. The diets of northern pike in the Salt River included 11 different fish species, accounting for 83% of all prey (by Relative Importance), two invertebrate orders (9%), and three terrestrial vertebrate taxa (8%). Suckers, burbot, ninespine stickleback and small lake whitefish were the most common prey species eaten by pike from the Salt River. Eleven of the 12 prey taxa taken by northern pike in the Slave River were fish species (95% Relative Importance); one invertebrate order (Plecoptera) was also found. Flathead chub, Arctic lamprey, burbot and emerald shiners were the most common prey species of northern pike from the Slave River near Fort Smith. Northern pike from the Slave Delta contained nine different prey types, of which seven were fish species (88% Relative Importance), one was an aquatic invertebrate order (8%) and one terrestrial vertebrate taxon (4%). Burbot, trout-perch and lake whitefish were the dominant prey consumed.

Table 2-3. Percent number, mass, and frequency of occurrence, and Relative Importance (RI) of prey taxa in the diet of northern pike in the lower Slave River system throughout all study sites and seasons in 1995, and the Relative Importance of prey taxa in 1994 (n=number of stomachs with prey suitable for calculation of RI). Scientific names of fish prey are in Table 1. See Appendix D for percent number, mass, and frequency of occurrence of prey taxa in the diet in 1994.

Prey Items	% Number	% Mass	% Frequency Occurrence	% RI n=82	1994 % RI n=26
Fish:				**(89.1%)**	**(93.4%)**
burbot	12.3	29.6	20.7	19.7	0
flathead chub	5.8	28.1	9.8	13.7	4.8
suckers[1]	8.7	9.0	14.6	10.2	8.7
lake whitefish	6.5	12.7	8.5	8.7	22.7
ninespine stickleback	20.3	0.2	4.9	8.0	0
trout-perch	10.9	0.4	11.0	7.0	0
Arctic lamprey	6.5	4.4	7.3	5.7	0
goldeye	4.3	2.2	7.3	4.4	6.3
emerald shiner	5.8	0.2	7.3	4.2	2.3
northern pike	2.2	3.3	3.7	2.9	32.0
walleye	1.4	4.4	2.4	2.6	8.9
cisco	0.7	0.6	1.2	0.8	0
lake chub	0.7	0.1	1.2	0.6	0
spottail shiner	0.7	0.1	1.2	0.6	7.7
Aquatic Invertebrates:				**(7.0%)**	**(4.4%)**
Amphipoda	2.9	0.0	3.7	2.1	0
Plecoptera	2.2	0.0	3.7	1.8	2.2
Zygoptera	2.2	0.0	3.7	1.8	0
Ephemeroptera	3.0	0.0	1.2	1.3	2.2
Terrestrial Vertebrates: [2]	2.8	4.8	4.8	**4.1**	2.2

[1] longnose and white suckers

[2] rodents, snakes and birds

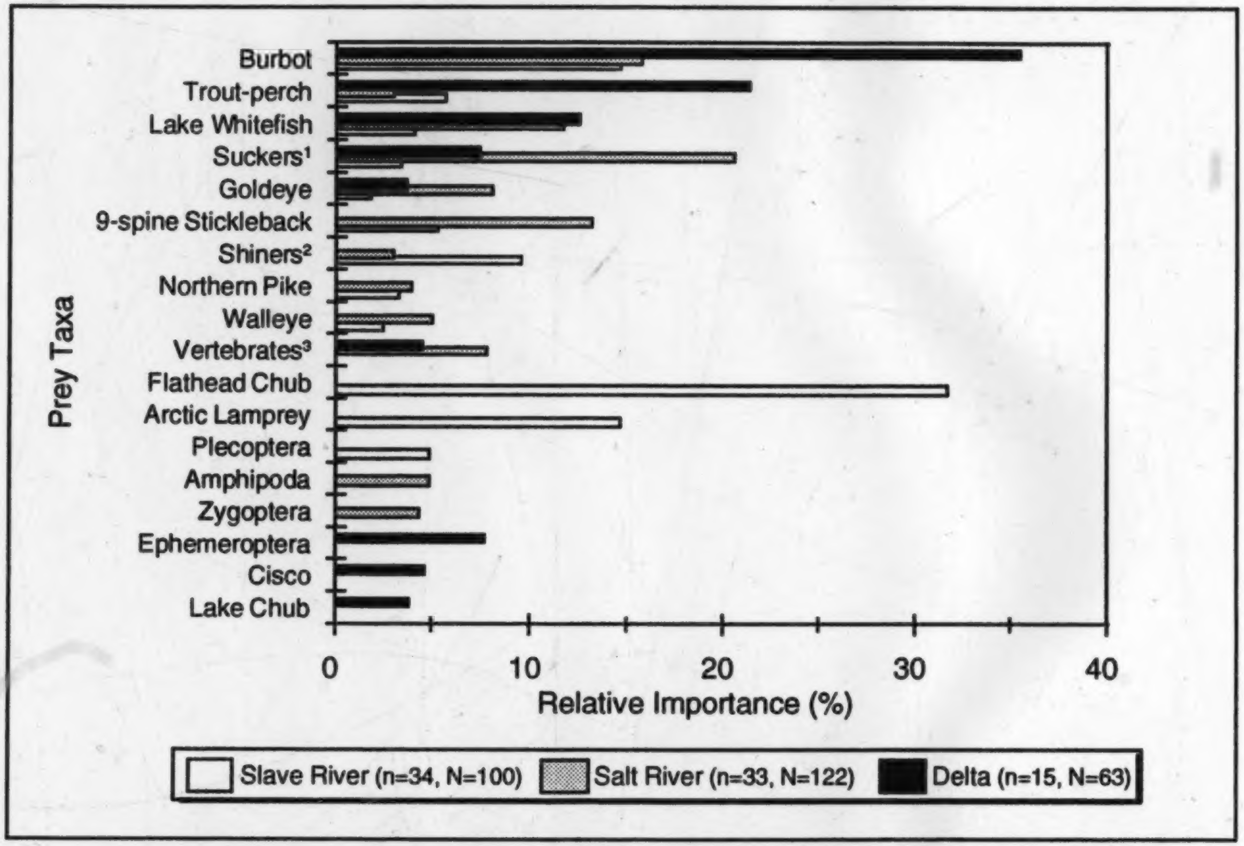


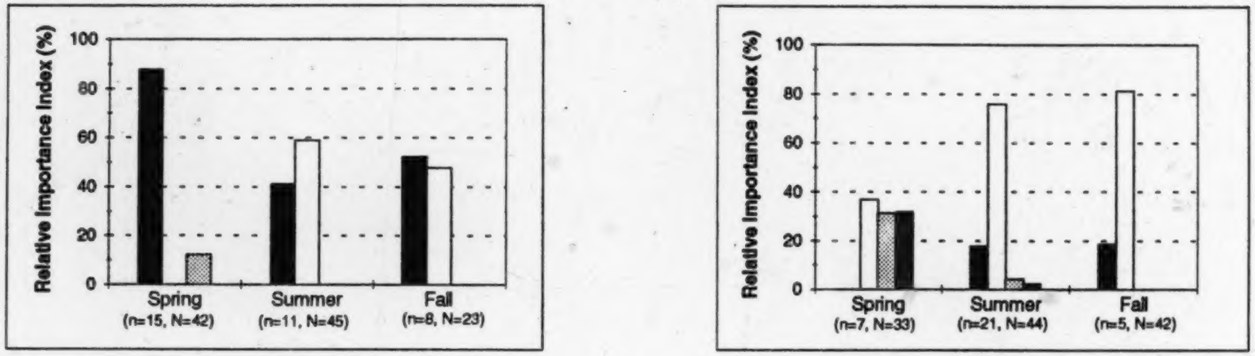
Figure 2-9. Relative Importance (%) of prey from northern pike in the Slave River system in 1995, where n is the number of stomachs containing prey suitable for the calculation of RI, and N is the total number of stomachs examined, excluding unsuitable prey. [1] indicates longnose and white suckers, [2] indicates emerald and spottail shiners, and [3] indicates rodents, snakes birds.

Seasonal Changes in Diet

The 1995 sampling period was divided into three seasons to examine seasonal changes in diet composition of northern pike. Seasons were classified as spring (May and June), summer (July and August) and fall (October). Prey were also grouped into four broader ecological categories: deep-dwelling fish, shallow-dwelling fish, aquatic invertebrates and terrestrial vertebrates (Appendix E). The designation of fish species was based on the literature and catches from gillnets and beach seines.

Seasonal dietary patterns were evident in each of the three study areas. In the Slave River, deep-dwelling fish were the most important prey in the spring, representing 88% of the diet by Relative Importance (Figure 2-10a). Flathead chub and Arctic lamprey were the dominant deep-dwelling prey at this time, representing 58% and 22%, respectively. The importance of deep-dwelling fish prey decreased to 41% in summer, then increased slightly to 52% in the fall. However, the importance of burbot as prey increased across seasons, attaining an importance of 38% in the fall. No identifiable shallow-dwelling species were present in spring, although, shallow-dwelling species increased considerably to 59% importance in summer and decreased slightly to 48% in the fall. Important shallow-dwelling species during the latter two seasons were trout-perch, emerald shiner, ninespine stickleback, and young-of-the-year (YOY) northern pike, walleye and longnose sucker. Of these shallow-dwelling prey, small northern pike and walleye were present in the diet only during summer, whereas ninespine sticklebacks and YOY longnose sucker were present only during the fall (RI values in Appendix E). Emerald shiner and trout-perch were important prey in both seasons. Invertebrate prey (Plecoptera) were only present in the diet during spring (12% relative importance).

In the Salt River, shallow-dwelling fish species were dominant in northern pike diets across all seasons and increased considerably in importance from the spring to summer and fall (Figure 2-10b). Important shallow dwelling species were small northern pike and lake whitefish in spring, whereas suckers, ninespine sticklebacks, lake whitefish and goldeye were most important in summer (RI values in Appendix E). Aquatic invertebrate prey (Zygopteran nymphs and amphipods) had their highest importance in spring (31.3% RI), decreased considerably in summer (4.2%) and disappeared in fall. Burbot was the only deep-dwelling species in the diet, occurring only in summer (17.6% RI) and fall (18.7%).


(a) Slave River

(b) Salt River

(c) Slave Delta

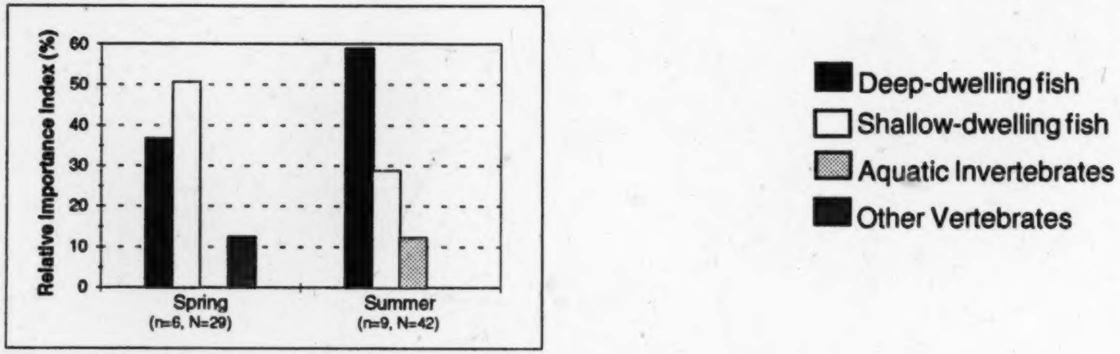


Figure 2-10. Seasonal variation in the diet of northern pike during 1995 in the (a) Slave River, (b) Salt River, and (c) Slave Delta, based on the Index of Relative Importance. See Appendix B for the four prey categories.

Terrestrial vertebrates were also found in the stomachs during spring and summer but were absent in the fall samples.

The diet analyses of northern pike from the Slave Delta showed shallow-dwelling fish species were the most important prey in spring (Figure 2-10c). Trout-perch were by far the most important shallow-dwelling prey throughout spring and summer, followed by lake cisco in the spring and small suckers in the summer. Deep-dwelling species, such as burbot and lake whitefish, increased in importance during the summer, whereas, the importance of shallow-dwelling species decreased. Rodents were found in the diet only during spring. Aquatic invertebrates were only present in one immature northern pike (203-mm FL) caught in a beach seine during summer.

Predator-Prey Size Relationships

There was a positive correlation between predator length and prey length (r^2=0.38, n=132) (Figure 2-11). Prey length increased with predator length, although large predators also consumed small prey items. The ratio of prey length to predator length ranged from 2 to 60% with an average of 22%.

Walleye (*Stizostedion vitreum*)

Stomach contents were determined for walleye collected in 1994 (n=68) and 1995 (n=206). A high percentage of fish had empty stomachs in both 1994 and 1995, comprising 57% and 75%, of the samples respectively.

Dietary information for 1994 was obtained only for the summer sampling period (July/August), from which 11 different prey taxa were found; six fish species (80% Relative Importance) and five aquatic invertebrate orders (20%)(Table 2-4). The most common prey found in the stomachs were northern pike and suckers. All fish prey had importance values exceeding those of aquatic invertebrates.

In 1995, 15 different prey taxa were documented (Table 2-4). Prey included nine fish species (78% Relative Importance) and six aquatic invertebrate orders (22%). The most common prey found in the stomachs were ninespine stickleback, trout-perch, Arctic lamprey and plecopterans.

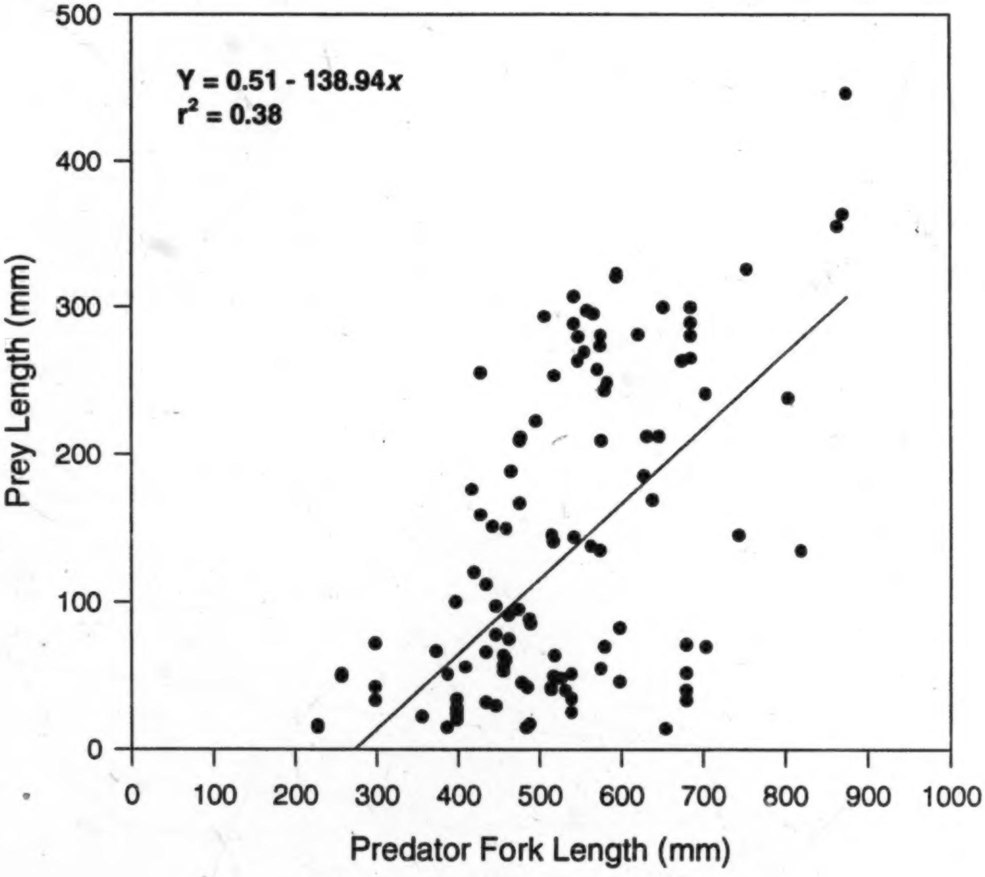


Figure 2-11: Relationship between northern pike fork length and length of prey.

Diet in Different Habitats

For 1995, the data were divided into the three main sampling locations: the Slave River at Fort Smith, the Salt River and the Slave Delta (Figure 2-12). Prey diversity was highest in the Salt River with 11 prey taxa followed by six prey taxa in the Slave River and three in the Slave Delta. Walleye in the Salt River ate six different fish species, accounting for 64% of all prey (by Relative Importance) and five aquatic invertebrate orders (36%). Emerald shiners, trout-perch, ephemeropterans and plecopterans were the most common prey items found. Of the walleye caught in the Slave River, four of the six prey taxa were fish species (83% Relative Importance) and two were aquatic invertebrate orders (17%). Ninespine sticklebacks, Arctic lamprey, trout-perch and plecopterans were the most important prey taxa for walleye from the Slave River. Walleye from the Slave Delta had three different prey taxa, of which two were fish (90% Relative Importance). Trout-perch were by far the most dominant prey eaten.

Seasonal Changes in Diet

Seasonal changes in the diet composition of walleye were examined during 1995. Data were divided into three seasons and prey taxa were grouped into four broader categories, as with northern pike diets (Appendix G).

As with northern pike, seasonal dietary patterns were evident in each of the three study areas. In the Slave River, shallow-dwelling fish prey were taken in all three sampling periods, whereas aquatic invertebrates were present only in spring and deep-dwelling fishes were consumed only in the summer sampling period (Figure 2-13a). For the spring and summer sampling periods, small northern pike and especially trout-perch were the main shallow-dwelling prey fish. For the fall sampling period, only four walleye were caught, of which only two had prey items; both stomachs contained large numbers of ninespine sticklebacks (37 and 42 each). Aquatic invertebrates were only present in the stomachs of walleye caught in spring, accounting for 47% of the diet by Relative Importance. The two main invertebrates were plecopteran nymphs and amphipods. Arctic lamprey were the only deep-dwelling prey during summer.

Table 2-4. Percent number, mass, and frequency of occurrence, and Relative Importance (RI) of prey taxa in the diet of walleye in the lower Slave River system throughout all study sites and seasons in 1995, and the Relative Importance of prey taxa in 1994 (n=number of stomachs with prey suitable for the calculation of RI). Scientific names of fish prey are in Table 1. See Appendix F for percent number, mass, and frequency of occurrence of prey taxa in the diet in 1994.

Prey Items	% Number	% Mass	% Frequency Occurrence	% RI n=37	1994 % RI n=22
Fish:				**(77.7%)**	**(79.6%)**
ninespine stickleback	56.3	30.7	8.1	29.6	0
trout-perch	11.3	26.1	27.0	20.0	7.7
Arctic lamprey	1.4	33.4	5.4	12.5	0
shiner[1]	3.5	5.7	13.5	7.1	6.5
flathead chub	1.4	0.5	5.4	2.3	7.2
northern pike	1.4	0.3	5.4	2.2	33.6
lake chub	0.7	1.3	2.7	1.5	0
walleye	0.7	1.1	2.7	1.4	7.2
sucker	0.7	0.2	2.7	1.1	17.4
Aquatic Invertebrates:				**(22.3%)**	**(20.4%)**
Plecoptera	11.3	0.3	24.3	11.2	4.8
Ephemeroptera	6.3	0.1	5.4	3.7	5.0
Amphipoda	1.4	0.1	5.4	2.2	0
Zygoptera	1.4	0.1	5.4	2.1	0
Diptera .	1.4	0.0	5.4	2.1	0
Trichoptera	0.7	0.0	2.7	1.1	4.8
Corixidae	0.0	0.0	0.0	0.0	3.4
Hymenoptera	0.0	0.0	0.0	0.0	2.4

[1] emerald and spottail shiners

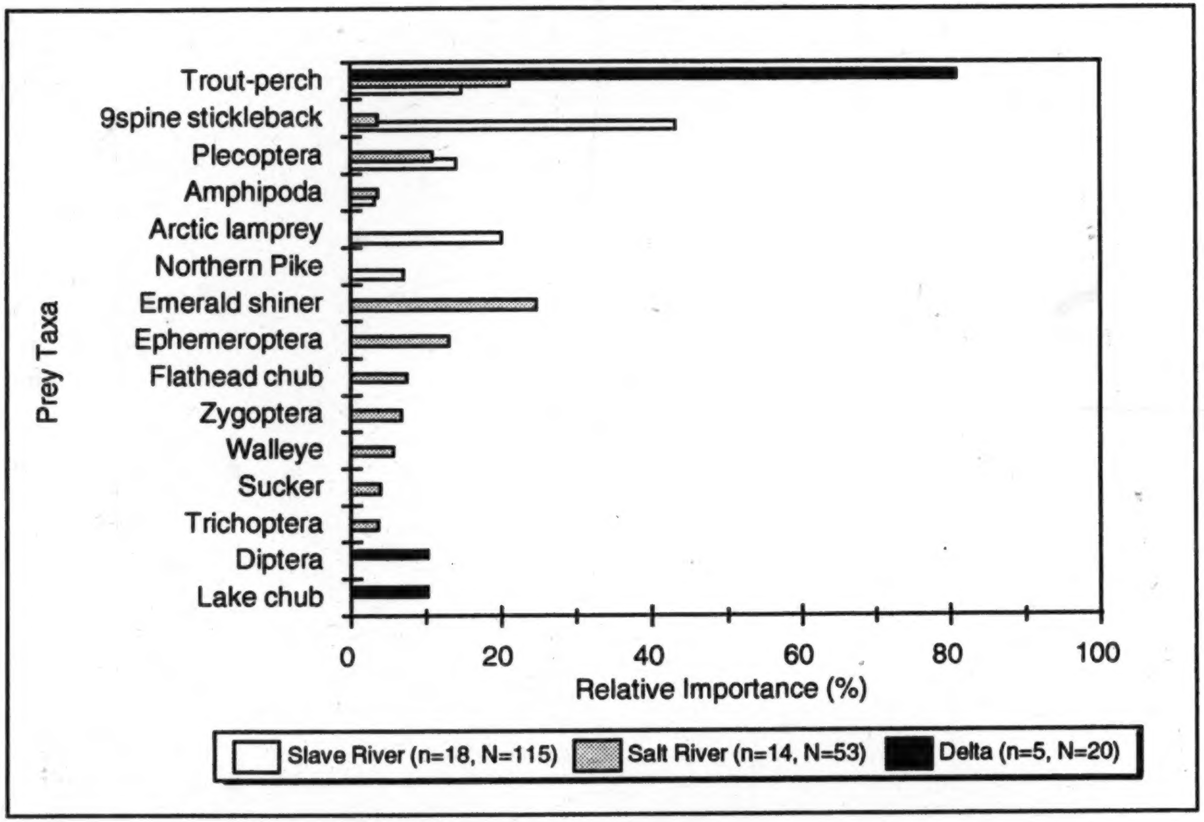
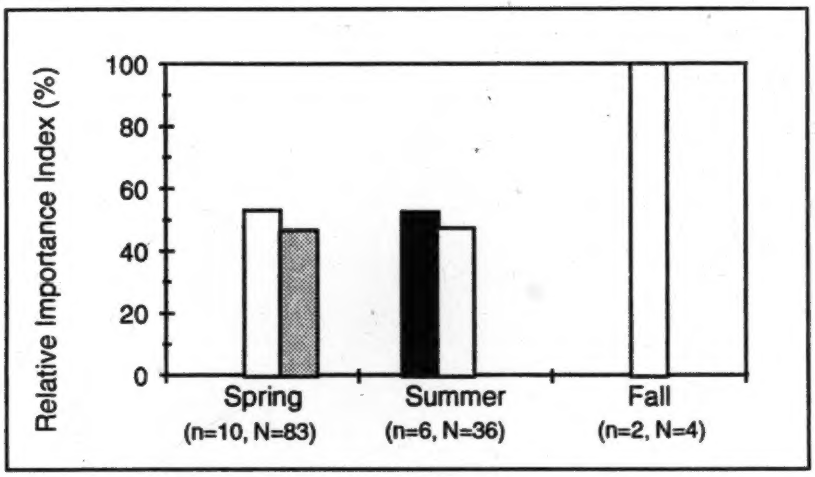


Figure 2-12. Relative Importance (%) of prey from walleye in the Slave River system, 1995, where n is the number of stomachs containing prey suitable for the calculation of RI, and N is the total number of stomachs examined, excluding unsuitable prey.

(a) Slave River



(b) Salt River

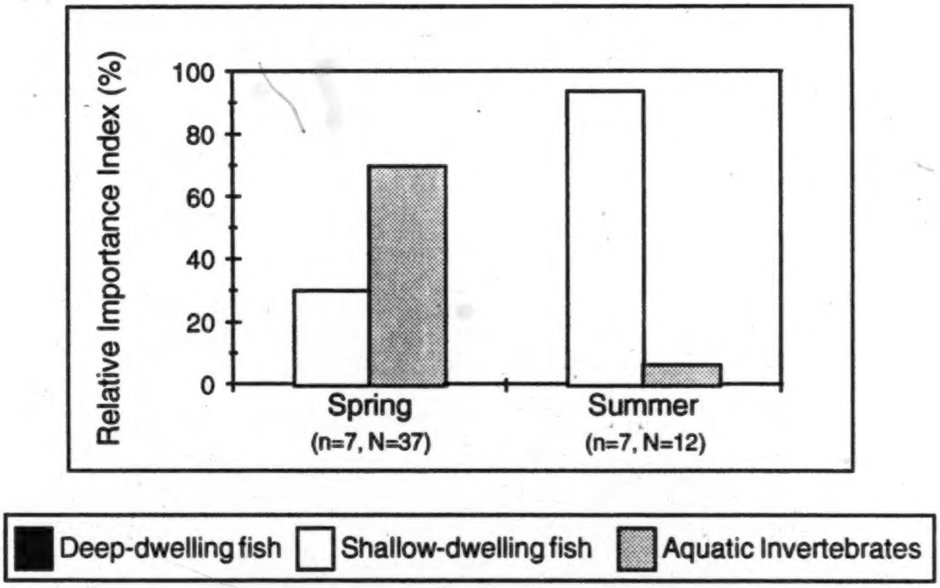


Figure 2-13. Seasonal variation in the diet of walleye during 1995 in the (a) Slave, and (b) Salt Rivers, based on the Index of Relative Importance (n is the number of stomachs with prey suitable for the calculation of RI, and N is the total number of stomachs, excluding unsuitable prey. See Appendix D for the three prey categories.

In the Salt River, aquatic invertebrates were the dominant prey in the diets of walleye during spring, with shallow-dwelling fish becoming dominant during summer (Figure 2-13b); no walleye were caught in the Salt River during the fall sampling period. Aquatic invertebrates comprised 70% of the diet by Relative Importance in spring, which decreased to 6% in summer. The dominant aquatic invertebrates during spring were ephemeropterans and plecopterans. Shallow-dwelling fish prey accounted for 30% of the diet by Relative Importance in spring, which increased to 94% in summer. Emerald shiners were the most important prey during both seasons. Trout-perch and YOY flathead chub were other important prey in summer.

Very few walleye were captured in the gillnets during the spring and summer sampling in the Slave Delta. Of the four walleye caught in spring, all had empty stomachs. Sixteen walleye were caught in summer, but only five had recognizable prey. Trout-perch were present in four of the five, achieving a relative importance of 81%; the remaining prey comprised lake chub and Diptera larvae (Appendix G).

Predator-Prey Size Relationships

Predator-prey size relationships were also examined for walleye. There was a weak positive correlation between prey length and predator length ($r^2 = 0.06$, $n = 53$) (Figure 2-14). The ratio of prey length to predator length ranged from 2 to 20% with a mean of 8%. Arctic lamprey (2 in total) were excluded from this analysis as outliers, since they were coiled up in the stomach; each Arctic lamprey had total length much greater than stomach length, thus the prey/predator ratios would be greatly overestimated if included.

Burbot (*Lota lota*)

Stomach contents were examined for 68 adult burbot caught in 1994 and 9 juvenile burbot from 1995. All adult burbot were caught in December 1994, prior to spawning. These burbot were primarily caught using baited set lines. A very high percentage had empty stomachs or minimal digested matter (74%). Only two different prey species were found in the stomachs, small goldeye (one stomach) and lake whitefish (two stomachs).

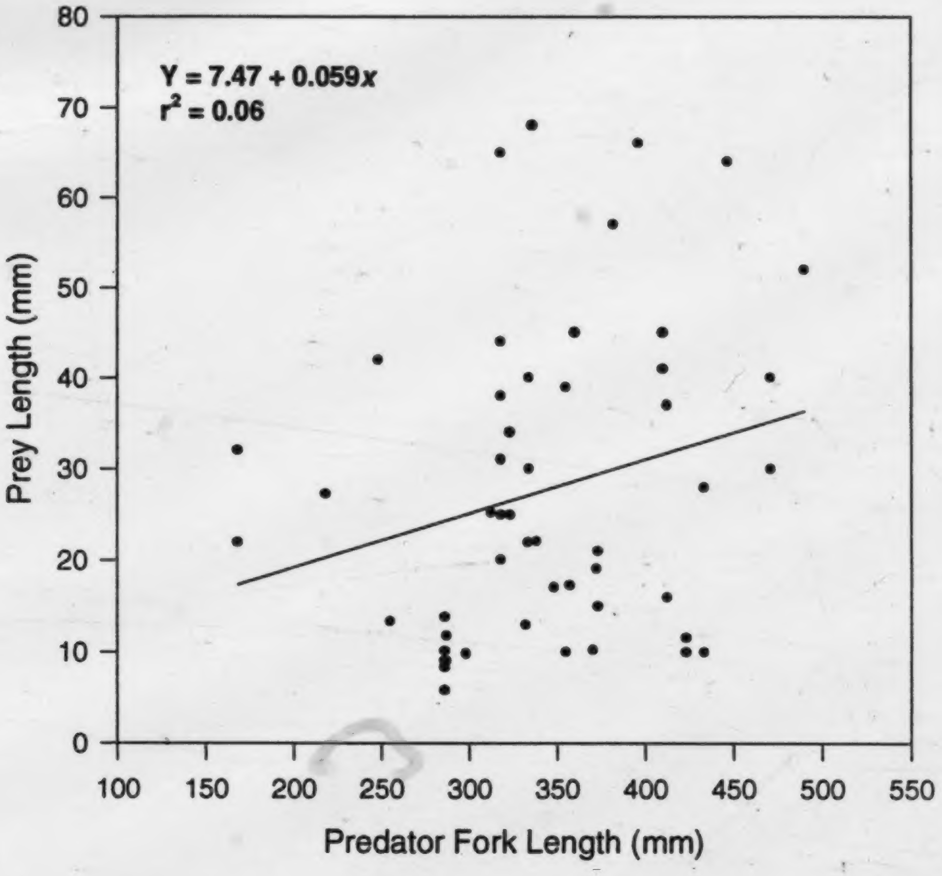


Figure 2-14: Relationship between walleye fork length and length of prey.

Because very few burbot were caught in the gillnets, most juvenile burbot that were analyzed for diet were individuals found in northern pike stomachs. These fish were caught in the summer and fall sampling periods. Total lengths ranged from 141 mm to 355 mm. Prey items were found in six of the nine (67%) stomachs analyzed. The four prey taxa identified included amphipods (three stomachs), ninespine stickleback (two stomachs), YOY longnose sucker (one stomach) and plecopteran nymphs (one stomach).

Inconnu (*Stenodus leucichthys*)

Stomach contents from inconnu were analyzed during the 1994 (n=84) and 1995 (n=51) sampling periods. Only 30 stomachs (22%) had prey items, of which 18 had recognizable prey. Five fish species were documented in the stomach contents. In 1994, northern pike were the most important prey of inconnu, followed by trout-perch and flathead chub (Table 2-5). In 1995, small lake whitefish were the most important prey, followed by trout-perch and longnose suckers, respectively (Table 2-5). All prey items were small fish, ranging from a 32-mm trout-perch to a 113-mm northern pike.

The diets of invertebrate feeders

Lake Whitefish (*Coregonus clupeaformis*)

In 1994, 78 lake whitefish stomachs were analyzed; 67 were from the Slave River, of which only 4 had prey items (6%); in contrast, 9 of 11 fish (82%) from the Salt River contained prey items. Five different prey taxa were documented in 1994 during the August sampling period, all of which were aquatic invertebrate taxa. Trichopterans were the dominant prey (Table 2-6). In 1995, 67 lake whitefish stomachs were analyzed from the Salt River, of which 47 had prey items (70%); from the Slave River, 37 stomachs were analyzed, but similar to 1994, only one contained a prey item. In addition, two lake whitefish were caught from the Delta in 1995, but both had empty stomachs. Fifteen different prey taxa were documented in 1995, 13 of which were aquatic invertebrate taxa (94% by Relative Importance); plant material represented 4%, and fish 2% (Table 2-6). The most common items found in the stomachs were ostracods followed by corixids and trichopterans.

Table 2-5. Percent number, mass, and frequency of occurrence, and Relative Importance (RI) of prey taxa in the diet of inconnu in the Slave River and Delta in 1995 and Relative Importance of prey taxa during 1994 (n=number of stomachs with prey suitable prey for calculation of RI). Scientific names of fish prey are in Table 1. See Appendix H for percent number, mass, and frequency of occurrence of prey taxa in the diet in 1994.

Prey Items	% Number	% Mass	% Frequency Occurrence	% RI n=8	1994 % RI n=10
lake whitefish	55.6	14.5	62.5	44.1	0.0
trout-perch	22.2	79.6	25.0	42.3	10.3
longnose sucker	22.2	6.0	12.5	13.6	0.0
northern pike	-	-	-	-	83.0
flathead chub	-	-	-	-	6.7

Table 2-6. Percent number, mass, and frequency of occurrence, and Relative Importance (RI) of prey taxa in the diet of lake whitefish in the Salt River throughout all seasons in 1995, and the Relative Importance of prey taxa in 1994. (n=number of stomachs with prey suitable for calculation of RI). See Appendix I for percent number, mass, and frequency of occurrence of prey taxa in the diet in 1994.

Prey Items	% Number	% Mass	% Frequency of Occurrence	%RI n=47	1994 % RI n=9
Aquatic Invertebrates:				**(93.6%)**	**(100%)**
Ostracoda	81.9	25.5	40.4	30.4	0.0
Corixidae	12.6	51.2	63.8	26.2	16.9
Trichoptera	1.9	6.4	40.4	10.0	38.7
Gastropoda	1.2	9.2	25.5	7.4	0.0
Amphipoda	0.6	1.0	19.2	4.3	0.0
Dytiscidae	0.3	0.7	17.0	3.7	19.7
Chironomidae	0.5	0.1	17.0	3.6	13.4
Ceratopogonidae	0.1	0.03	12.8	2.7	0.0
Tabanidae	0.4	2.9	8.5	2.4	0.0
Ephemeroptera	0.04	0.1	6.4	1.3	0.0
Diptera larvae	0.3	0.02	2.1	0.5	11.4
Zygoptera	0.01	0.2	2.1	0.5	0.0
Oligochaeta	0.01	0.00	2.1	0.4	0.0
Plant Material	**0.1**	**0.3**	**19.2**	**4.0**	**0.0**
Fish	**0.1**	**2.4**	**10.6**	**2.7**	**0.0**

Seasonal Changes in Diet

During 1995, ostracods were the dominant prey for lake whitefish in the Salt River during spring, comprising 52.5% by Relative Importance (Figure 2-15; Appendix J). The importance of ostracods decreased to 6.2% in summer, and no ostracods were present in the fall samples. Corixids were the dominant prey during summer (27.7%RI) and fall (67.5%). The importance of both trichopteran larvae and fish doubled between spring and summer, before disappearing from the diet in the fall. Gastropods increased in importance from spring (2.3%) to summer (15.7%) and subsequently decreased in the fall (8.8%).

Goldeye (*Hiodon alosoides*)

Stomach contents were analyzed for 131 goldeye caught in 1994, of which only 35 had prey items. Thirteen different prey taxa were identified; this included seven aquatic invertebrate taxa (42%RI), three terrestrial insect taxa (35%), terrestrial vertebrates (12%), fish (6%) and plant material (5%). Terrestrial insects included adult Odonata, Orthoptera and Hymenoptera. Of the aquatic invertebrates, dytiscids and corixids were the most important prey taxa (Appendix K). For the 1995 sampling period, a much larger proportion (56 of 74) of the goldeye examined contained prey in their stomachs. Sixteen different prey taxa were identified (Figure 2-16); 12 aquatic invertebrate taxa (78% by Relative Importance), two terrestrial insect taxa (8%), a terrestrial vertebrate (12%) and plant material (3%). The dominant prey taxa were clam shrimps (Branchiopoda), corixids, rodents and plecopterans (Appendix L).

Diet in Different Habitats

The 1995 stomach content data were divided into three sampling locations, the lower Slave River at Fort Smith, the Salt River and the Slave Delta (Figure 2-16). Over all seasons, goldeye caught in the Slave River had eight different prey taxa, compared with nine different prey taxa in the Salt River and 12 in the Slave Delta. The diets of goldeye caught in the Slave River had five different aquatic invertebrate taxa, accounting for 83% of all prey by Relative Importance; other food categories included two terrestrial insect orders (5%), one terrestrial vertebrate taxon (7%) and plant material (5%). Corixids were the dominant prey type, followed by

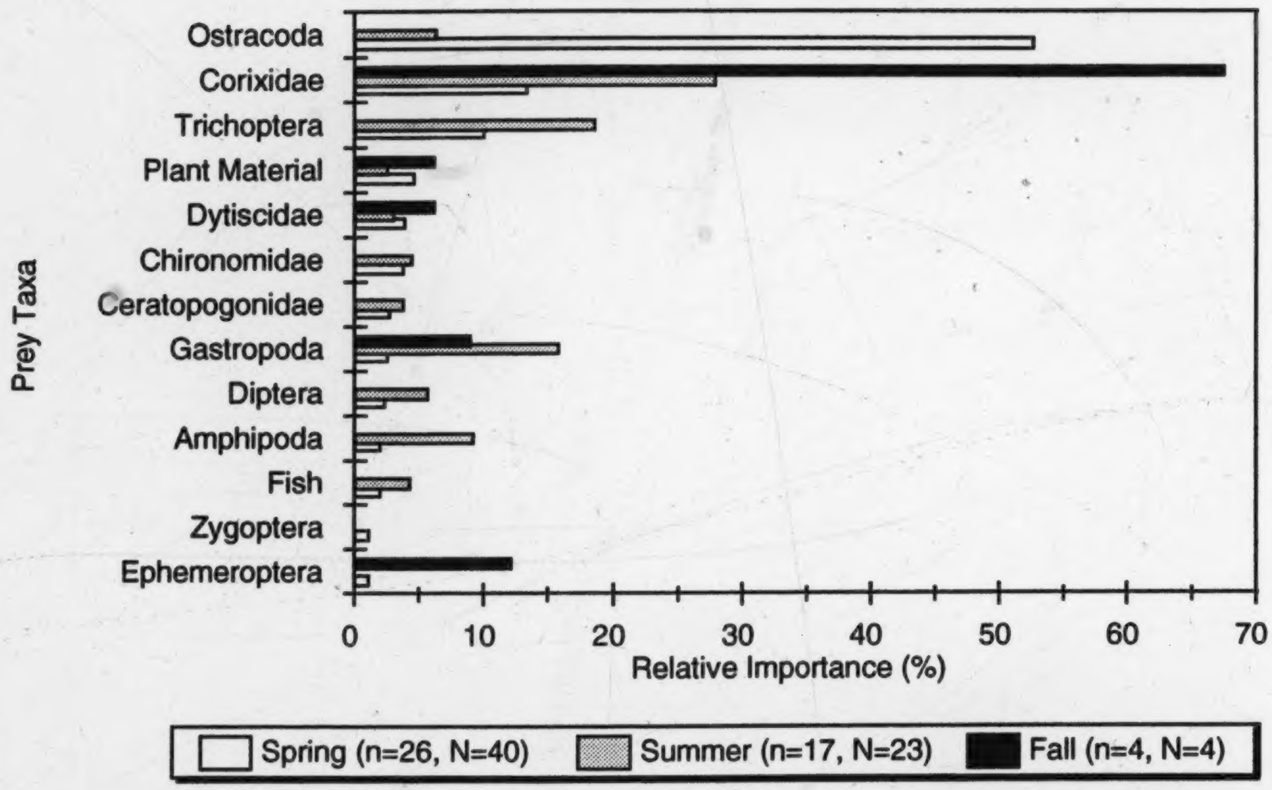


Figure 2-15. Seasonal variation in the diet of lake whitefish in the Salt River, 1995 based on the Index of Relative Importance (n=number of stomachs containing prey suitable for the calculation of RI, and N=total number of stomachs, excluding unsuitable prey).

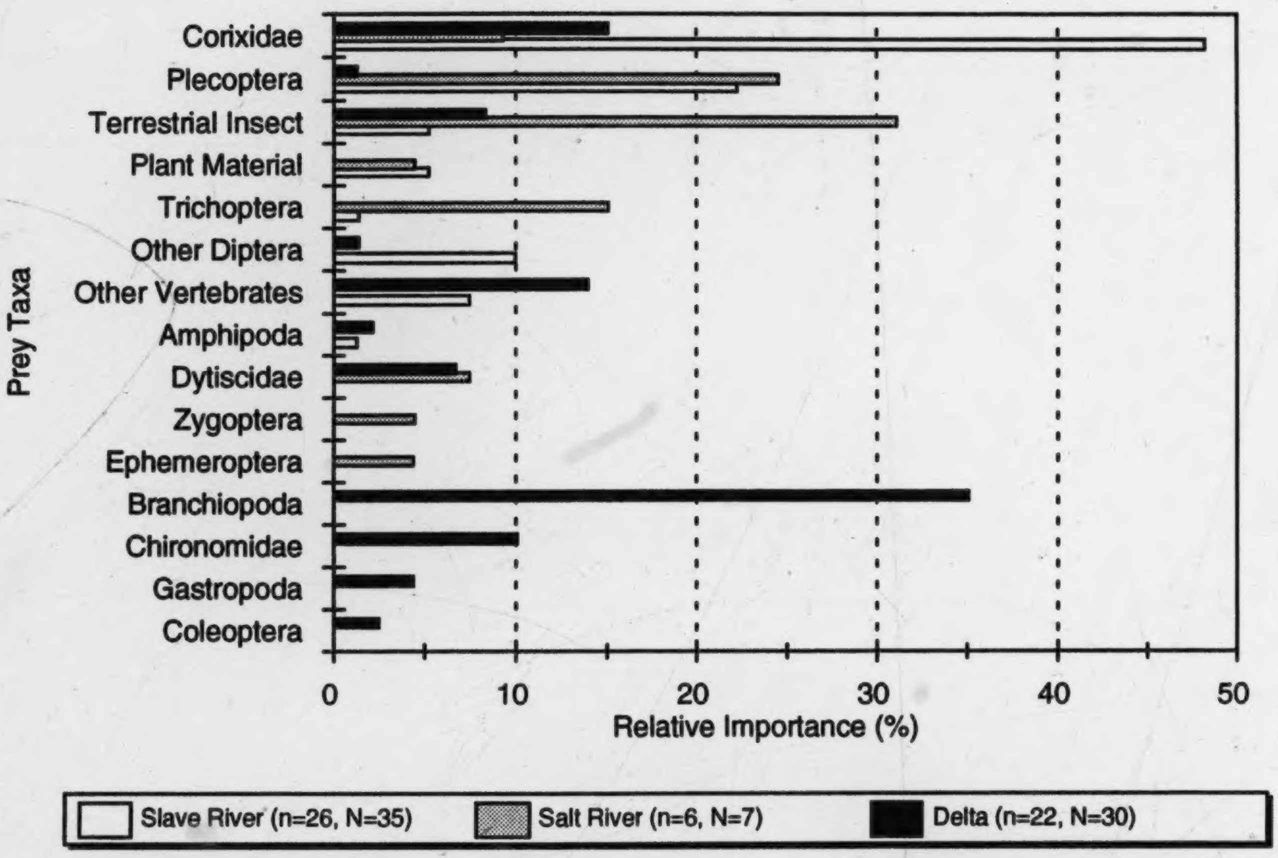


Figure 2-16. Relative Importance (%) of prey from goldeye in the Slave River system in 1995 (n= number of stomachs with prey suitable for the calculation of RI, N= total number of stomachs examined).

plecopterans. Of the goldeye caught in the Slave Delta, nine of the 12 prey taxa found were aquatic invertebrates (78% Relative Importance); other prey included terrestrial insects (8%) and rodents (14%). Clam shrimp were the main prey, followed by corixids and chironomids. Goldeye from the Salt River had nine different prey types, six of which were aquatic invertebrate orders (65% Relative Importance); terrestrial insects were also important (31%). Terrestrial insects and plecopterans were the principal prey.

Seasonal Changes in Diet

Seasonal patterns in the diet of goldeye were examined during 1995 for each of the three sampling locations. Seasonal variation was evident for all three locations.

In the Slave River, plecopterans were the most dominant prey in the goldeye diet during spring and summer, however, no plecopteran nymphs were present during the fall (Table 2-7). Corixids were present in all three seasons and were by far the most important prey type in the fall. Terrestrial insects and dytiscids were also present in all three seasons and both reached their highest importance during summer. Plant material was present during spring and summer, whereas rodents and ephemeropterans were present only in the fall samples.

In the Slave Delta, clam shrimp were the most important prey in goldeye diets during spring, but their importance decreased considerably in summer (Table 2-7). Corixids, gastropods, dytiscids and dipteran larvae were also found in the diet during both seasonal periods, whereas rodents, chironomids and terrestrial insects were prey types that were only found in the diets during summer.

In the Salt River, there was a much greater diversity of prey types in spring than summer (Table 2-7). Of the six prey taxa present in the spring, plecopterans and trichopterans were the most important. Corixids and terrestrial insects were the only two prey types present in the diet of goldeye during summer; not surprisingly, both increased substantially in relative importance from spring. No goldeye were captured in the Salt River during the fall sampling period.

During 1994, diet information for goldeye was obtained only for the Slave River during the summer sampling period, precluding seasonal analysis (Table 2-7). However, some differences

Table 2-7. Seasonal variation in the Relative Importance (%) of prey for goldeye in the Slave River system in 1995 and the summer season for the Slave River in 1994.

Prey Items	Slave River			Salt River			Slave Delta		Slave River 1994
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Summer
Aquatic Invertebrates:	**(83.3)**	**(68.3)**	**(83.8)**	**(82.1)**	**(55.0)**	**(0.0)**	**(100)**	**(67.3)**	**(41.7)**
Plecoptera	47.0	49.0	0.0	34.1	0.0	0.0	0.0	1.4	8.3
Corixidae	24.6	3.6	69.1	6.0	55.0	0.0	8.4	17.2	11.1
Dytiscidae	8.2	15.7	10.3	9.4	0.0	0.0	8.4	6.9	12.7
Amphipoda	3.6	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0
Trichoptera	0.0	0.0	0.0	20.6	0.0	0.0	0.0	0.0	6.1
Zygoptera	0.0	0.0	0.0	6.2	0.0	0.0	0.0	0.0	0.0
Ephemeroptera	0.0	0.0	4.5	5.9	0.0	0.0	0.0	0.0	1.2
Clam Shrimp	0.0	0.0	0.0	0.0	0.0	0.0	62.7	13.2	0.0
Gastropoda	0.0	0.0	0.0	0.0	0.0	0.0	12.2	1.7	0.0
Diptera	0.0	0.0	0.0	0.0	0.0	0.0	8.3	1.4	1.2
Chironomidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.5	1.2
Coleoptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0
Terrestrial Insects:	**4.0**	**25.6**	**4.6**	**11.7**	**45.0**	**0.0**	**0.0**	**12.2**	**35.4**
Terrestrial Vertebrates:	**0.0**	**0.0**	**11.6**	**0.0**	**0.0**	**0.0**	**0.0**	**20.5**	**11.9**
Fish:	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**5.7**
Plant Material:	**12.7**	**6.1**	**0.0**	**6.2**	**0.0**	**0.0**	**0.0**	**0.0**	**5.3**

between years were evident. The total number of prey taxa documented in summer 1994 was 11, compared with only seven in 1995. In both years, aquatic invertebrates were the main prey, followed by terrestrial insects. In 1994, terrestrial vertebrates (rodents) and aquatic vertebrates (fish) represented 12% and 5% of the diet by relative importance, but were absent in the diets of goldeye in the Slave River during 1995.

Flathead Chub (*Platygobio gracilis*)

A total of 37 stomachs were analyzed from flathead chub collected in the Slave and Salt Rivers from 1994 and 1995, of which 19 (51%) contained prey items. Ten different prey categories were documented. In the Slave River, the flathead chub diet consisted of six aquatic invertebrate taxa (82% RI) and two terrestrial insect taxa (18%). There was no single dominant prey when all seasons were combined (Appendix M). There were, however, seasonal patterns evident (Table 2-8). Plecopterans and trichopterans were most important in spring, but both decreased in importance in summer; "other coleopterans" also decreased between spring and summer. Chironomids and especially terrestrial insects, which were the most important prey in summer, increased from spring to summer. In the Salt River, only four prey categories were documented, with gastropods and corixids being the most important prey consumed (Table 2-8).

Longnose Sucker (*Catostomus catostomus*)

Stomach contents were examined for 16 longnose suckers collected in the Salt River during 1995, of which nine had stomach contents. A total of ten different food categories were documented, including seven aquatic invertebrate taxa, one order of terrestrial insects, plant material (leaves, seeds, grasses) and detritus (Figure 2-17). Prey diversity was higher in spring than in summer (10 versus 5 prey taxa, respectively) (Table 2-9). Of the animal prey, ostracods were most important during both seasons, whereas, chironomids increased substantially in importance during summer. The amount of plant material in the diet decreased considerably in the latter part of the summer, and detritus increased slightly.

Table 2-8. Seasonal variation in the Relative Importance (%) of prey for flathead chub in the Slave and Salt Rivers in 1995.

Prey Items	Slave River Spring	Summer	Salt River Spring
Aquatic Invertebrates:	**(93.1)**	**(71.2)**	**(80.6)**
Plecoptera	21.1	9.7	0.0
Trichoptera	19.9	6.8	0.0
Dytiscidae	19.6	16.2	0.0
other Coleoptera	15.6	7.1	0.0
Corixidae	11.8	14.0	29.7
Chironomidae	5.1	17.5	0.0
Gastropoda	0.0	0.0	50.9
Terrestrial Insects:	**6.9**	**28.8**	**10.3**
Plant Material:	**0.0**	**0.0**	**9.1**

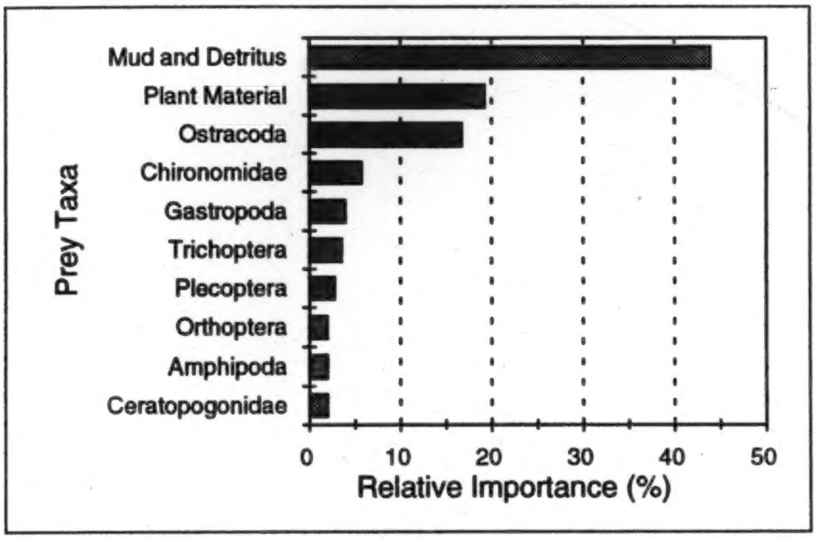


Figure 2-17. Relative Importance (%) of prey from longnose suckers in the Salt River, 1995.

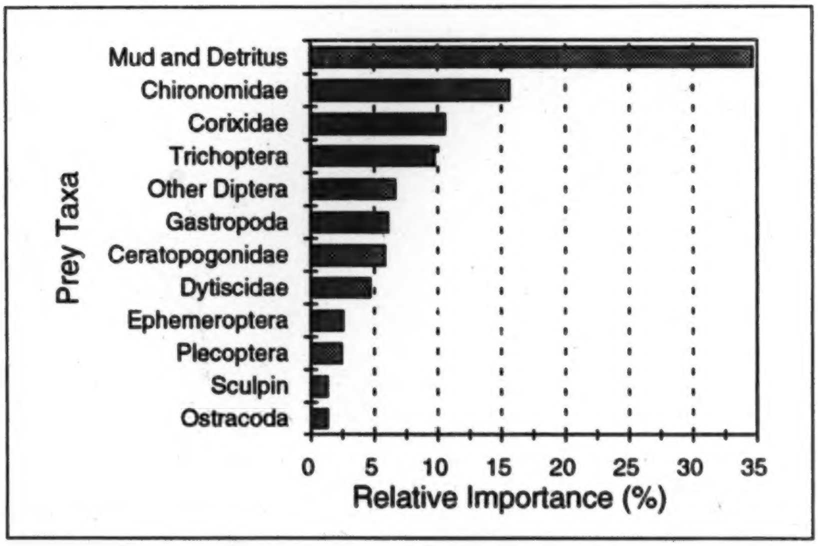


Figure 2-18. Relative Importance (%) of prey from white suckers in the Salt River, 1995.

Table 2-9: Seasonal variation of the Relative Importance (%) of prey for longnose sucker in the Salt River in 1995.

Prey Items	Spring	Summer
Aquatic Invertebrates:	**(38.9)**	**(37.6)**
Ostracoda	15.9	16.7
Chironomidae	4.0	14.2
Trichoptera	2.7	6.8
Gastropoda	4.8	0.0
Plecoptera	3.5	0.0
Amphipoda	2.7	0.0
Ceratopogonidae	2.7	0.0
Orthoptera	2.7	0.0
Plant Material:	**22.7**	**6.3**
Detritus:	**38.4**	**56.1**

Table 2-10: Seasonal variation of the Relative Importance (%) of prey for white sucker in the Salt River in 1995.

Prey Items	Spring	Summer	Fall
Aquatic Invertebrates:	**(58.1)**	**(62.6)**	**(70.7)**
Chironomidae	14.9	10.4	16.9
Corixidae	13.1	7.3	7.7
Gastropoda	8.5	3.5	4.6
Trichoptera	8.3	10.4	8.1
Dytiscidae	5.5	3.4	4.6
Ephemeroptera	2.7	0.0	4.9
Other Diptera	2.7	7.0	9.6
Ostracoda	2.7	0.0	0.0
Ceratopogonidae	0.0	13.9	14.2
Plecoptera	0.00	6.8	0.0
Fish:	**(0.0)**	**(3.5)**	**(0.0)**
Sculpin	0.0	3.5	0.0
Detritus:	**41.9**	**33.9**	**29.3**

White Sucker (*Catostomus commersoni*)

Stomach content analysis was conducted on 15 white suckers collected in the Salt River during 1995, of which 14 contained prey. Twelve different food categories were documented, including ten aquatic invertebrate taxa, one fish species, and detritus; the latter occurred most frequently in the diets. Chironomids were the most frequently occurring animals in the diet (Figure 2-18). Although there was a wide variety of prey present in the diet of white suckers throughout all seasons, seasonal variation was not as evident in white suckers as it was for most other species present in the Salt River (Table 2-10). Detritus represented a substantial amount of the diet throughout each season, while chironomids and ceratopogonids were the dominant animal prey.

Trophic Relations within the Fish Assemblages of the lower Slave River

Schoener's dietary overlap index for fishes in all study areas showed 3 different food relationships, no overlap (<0.05), a low degree of overlap (<0.3), and a moderate degree of overlap (>0.3 to <0.7). There were no species pairs exhibiting a high degree of overlap (>0.7) for any of the 3 sites.

Trophic Relations in the Slave River

Diet overlap within the fish community of the Slave River near Fort Smith was generally low throughout all seasons (Table 2-11). The main fishes feeding in the spring and summer were northern pike, walleye, goldeye and flathead chub. During the spring, goldeye showed a moderate degree of overlap with walleye and flathead chub, due to the common prey base of plecopterans; all other pairwise overlap values were low (≤ 0.21). Trophic relations between northern pike and walleye increased in summer to a moderate degree of overlap as walleye shifted to a more piscivorous diet, with a common prey base of Arctic lamprey, trout-perch and young northern pike. Goldeye and flathead chub maintained a moderate degree of overlap. During the fall, northern pike and walleye were the only species present that showed any overlap, however the overlap was low, where ninepine stickleback were the only common prey base consumed.

Table 2-11. Seasonal variation in the diet overlap between fishes in the Slave River, 1995, using Schoener's index (1974). Dashes indicate the absence of one of the species-pair combinations.

	WALL	GOLD	FHCB	LNSK	LKWT	INCO
Spring						
Northern pike (NTPK)	0.12	0.12	0.12	0	---	---
Walleye (WALL)		0.41	0.21	0	---	---
Goldeye (GOLD)			0.45	0	---	---
Flathead chub (FHCB)				0	---	---
Longnose sucker (LNSK)					---	---
Summer						
Northern pike (NTPK)	0.31	0	0	---	0	0
Walleye (WALL)		0	0	---	0	0
Goldeye (GOLD)			0.55	---	0	0
Flathead chub (FHCB)				---	0	0
Lake whitefish (LKWT)				---		0
Inconnu (INCO)				---		
Fall						
Northern pike (NTPK)	0.15	0	---	---	0	0
Walleye (WALL)		0	---	---	0	0
Goldeye (GOLD)			---	---	0	0
Lake whitefish (LKWT)			---	---		0
Inconnu (INCO)			---	---		

The DCA ordinations arranged the diet data for the Slave River fish assemblages along two readily interpretable axes, with eigenvalues of 0.94 and 0.40 (axis I and axis II, respectively). The ordination of species by season contrasts invertebrate feeders (i.e., goldeye and flathead chub) with piscivores (i.e., northern pike and walleye), especially along axis I (Figure 2-19a). The two extremes in diet, represented by fall collections of walleye and goldeye, were the two endpoints along axis I (Figure 2-19b); these corresponded with the positions of their major prey, ninespine sticklebacks for walleye and ephemeropterans and terrestrial vertebrates for goldeye (Figure 2-19a). Piscivores consumed some invertebrates in the spring and summer and thus were arranged in the middle of the ordination. Axis II contrasted walleye in the summer and their main prey (trout-perch) with northern pike in the spring and their prey (flathead chub and goldeye).

To illustrate the degree of overlap between species and seasons (spring and summer only), polygons that encompassed prey items representing RI's >5% were drawn into the ordination (Figures 2-19c and d). This showed clearly that: (i) most fishes exhibited seasonal variation in diet, as illustrated by the different shapes of polygons between Figure 2-19 c and d, (ii) overlap between piscivores and invertebrate feeders was more prominent in the spring, with plecopterans and amphipods being the common prey base, whereas no overlap occurred in the summer, (iii) northern pike was the top predator across both seasons, consuming primarily fish prey including walleye, but also terrestrial vertebrates and aquatic invertebrates, (iv) walleye more closely resembled the northern pike diet during the summer than the spring, and (v) goldeye and flathead chub were similar in diet composition during both spring and summer, however, they were much more similar during the summer months, due primarily to the common prey base of surface insects, dytiscids and plecopterans.

Trophic Relations in the Salt River

The trophic relations in the Salt River were more complex than those of the Slave River since more fishes occurred here, particularly invertebrate feeders. Overall, trophic relations among species were most similar in spring.

Northern pike and walleye showed little overlap during spring, and summer (Table 2-12). As in the Slave River, walleye and goldeye had a moderate degree of overlap in spring,

Figure 2-19. Detrended Correspondence Analysis of trophic relations in the Slave River, 1995. (a) Prey species scores, and (b) Predator species scores. Polygons that encompass prey with RI values >5% for each predator in the (c) spring and (d) summer.

Legend:

—— northern pike, -·-· walleye, — — goldeye, and ······· flathead chub

Seasons: 1= spring, 2=summer, 3=fall
Predators: N=northern pike, W=walleye, G=goldeye, F=flathead chub
Fish Prey: AL=Arctic lamprey, BR=burbot, EM=emerald shiner, FH=flathead chub, GD=goldeye, LK=lake whitefish, LN=longnose sucker, 9SB=ninespine stickleback, NP=northern pike, TP=trout-perch, WL=walleye
Invertebrate Prey: Am=Amphipoda, Ch=Chironomidae, Col=other coleoptera, Cx=Corixidae, Dy=Dytiscidae, Ep=Ephemeroptera, Pl=Plecoptera, Ter=terrestrial insects, Tr=Trichoptera
Other Prey: VT=other vertebrates, Veg=plant material

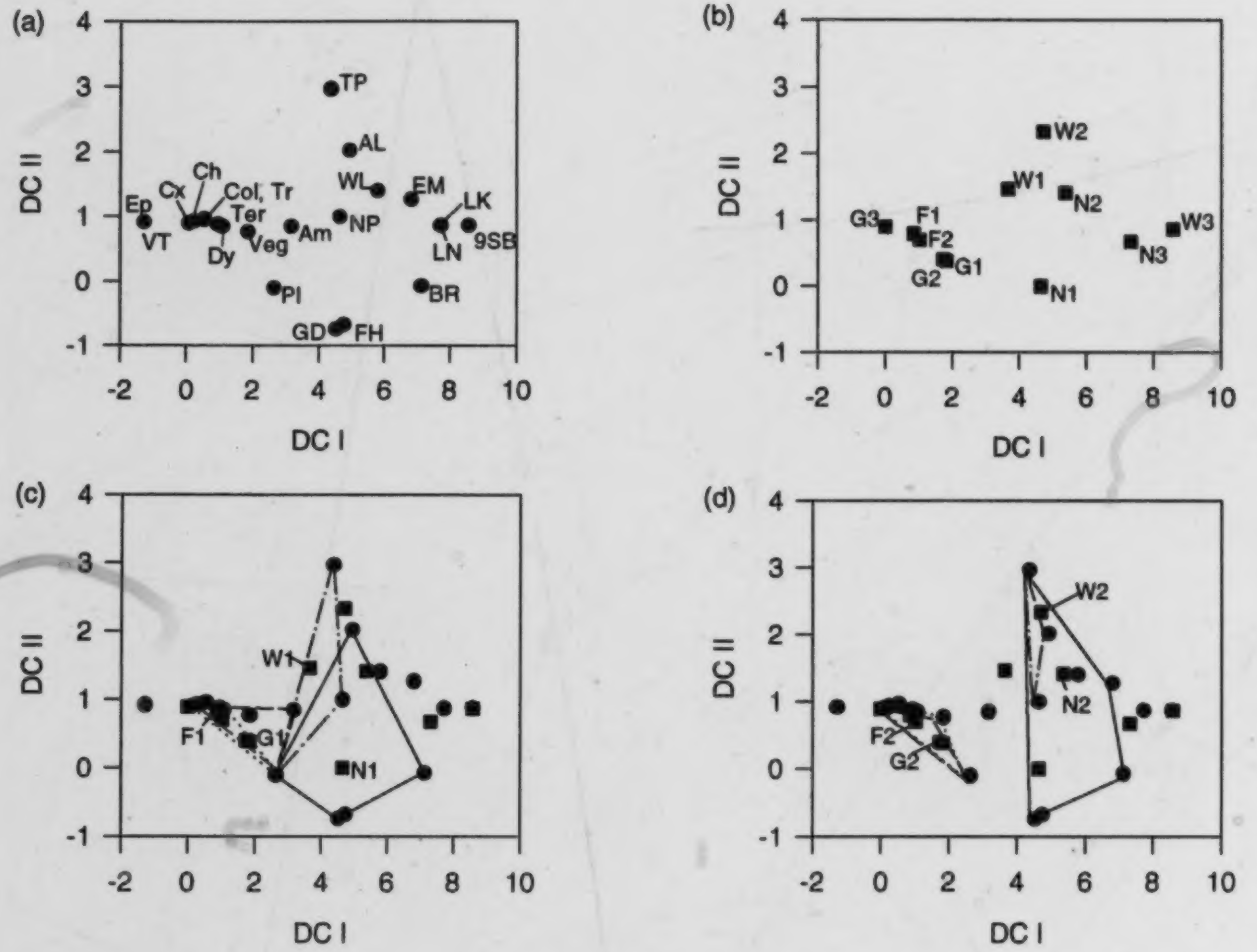

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Table 2-12. Seasonal variation in the diet overlap between fishes in the Salt River, 1995, using Schoener's index (1974). Dashes indicate the absence of one of the species-pair combinations.

	WALL	GOLD	LKWT	FHCB	WTSK	LNSK
Spring						
Northern pike (NTPK)	0.20	0.06	0.03	0	0	0.03
Walleye (WALL)		0.37	0.10	0	0.09	0.09
Goldeye (GOLD)			0.26	0.23	0.22	0.15
Lake whitefish (LKWT)				0.20	0.37	0.33
Flathead chub (FHCB)					0.22	0.17
White sucker (WTSK)						0.53
Summer						
Northern pike (NTPK)	0.26	0	0.06	---	0	0
Walleye (WALL)		0	0.04	---	0.06	0
Goldeye (GOLD)			0.28	---	0.07	0
Lake whitefish (LKWT)				---	0.37	0.20
White sucker (WTSK)				---		0.51
Longnose sucker (LNSK)				---		
Fall						
Northern pike (NTPK)	---	---	0	---	0	---
Lake whitefish (LKWT)	---	---		---	0.22	---
White sucker (WTSK)	---	---		---		---

Table 2-13. Seasonal variation in the diet overlap between fishes in the Slave Delta, 1995, using Schoener's index (1974). Dashes indicate the absence of one of the species-pair combinations.

	WALL	GOLD	INCO	LKWT
Spring				
Northern pike (NTPK)	0	0	---	---
Walleye (WALL)		0	---	---
Goldeye (GOLD)			---	---
Summer				
Northern pike (NTPK)	0.12	0	0.38	0
Walleye (WALL)		0.01	0.42	0
Goldeye (GOLD)			0.00	0
Inconnu (INCO)				0

contributed primarily by the common prey base of plecopterans, ephemeropterans, and zygopterans; other pairs exhibiting a moderate degree of overlap were lake whitefish with longnose sucker and white sucker, with a common prey base of ostracods and chironomids. Longnose sucker and white sucker showed the highest degree of moderate overlap in both the spring and summer compared to all other species-pair combinations, contributed mostly by overlap in consumption of ostracods, chironomids and trichopterans. During the fall, few fish were feeding.

The DCA ordinations summarized trophic relations for the Salt River fish assemblages along two readily interpretable axes, having eigenvalues of 0.90 and 0.57 (axis I and axis II, respectively). The ordination of species by season contrasts piscivores with invertebrate feeders along axis I (Figure 2-20b). As in the Slave River, fishes with mixed diets, primarily in the spring, were arranged in the middle of the ordination. The two extremes in diet, represented by summer collections of longnose sucker and fall collections of northern pike, were the two endpoints along axis I (Figure 2-20b); these corresponded with the positions of their major prey, detritus and chironomids for longnose suckers, and young-of-the-year longnose suckers for northern pike (Figure 2-20a). Axis II contrasted the summer diet of longnose sucker with that of goldeye in the summer, when the main prey were terrestrial insects.

Dietary polygons for the Salt River fish assemblage (Figures 2-20c and d) showed that: (i) most fishes exhibited seasonal variation in diet, (ii) diet overlaps of northern pike and walleye with invertebrate feeders, particularly goldeye, occurred mainly in the spring, more so for walleye than northern pike, (iii) the diets of lake whitefish and white suckers widened during the summer season to include prey such as plecopterans and sculpins for white suckers and gastropods, amphipods and ninespine sticklebacks for lake whitefish; and, (iv) in contrast, goldeye diet narrowed considerably to include primarily corixids and terrestrial insects.

Trophic Relations in the Slave Delta

There was no overlap in diet among fishes in the Slave Delta during the spring sampling period; during this time northern pike and goldeye were the only fishes caught that were feeding. During summer, the only species pairs that showed a moderate degree of overlap were inconnu-northern pike and inconnu-walleye (Table 2-13). Goldeye was the only species feeding on invertebrates and rodents. No samples were collected during the fall.

The DCA ordinations arranged the diet data for the Slave Delta fish assemblages along two readily interpretable axes, with eigenvalues of 0.94 and 0.46 (axis I and axis II, respectively). The ordination of species by season contrasts the three piscivores with the invertebrate feeder, goldeye, along axis I (Figure 2-21b). Goldeye in the summer and their prey (clam shrimp, dipteran larvae and gastropods) had the highest scores on axis I, whereas inconnu in summer and their prey (YOY longnose suckers and lake whitefish) had the lowest scores (Figures 2-21a and b, respectively). Axis II contrasted walleye in the summer and their major prey (trout-perch and lake chub with northern pike in the summer and their main prey (burbot, goldeye, longnose suckers and lake whitefish).

Dietary polygons for the Slave Delta fish assemblage (Figure 2-21c and d) showed that: (i) northern pike were the top piscivores across both seasons, (ii) goldeye were the only invertebrate feeders, (iii) overlap between piscivores and invertebrate feeders was not observed, (iv) among the piscivores, inconnu diets were intermediate between those of northern pike and walleye, and (v) northern pike and goldeye exhibited seasonal variation in diet.

Figure 2-20. Detrended Correspondence Analysis of trophic relations in the Salt River, 1995. (a) Prey species scores, and (b) Predator species scores. Polygons that encompass prey with RI values >5% for each predator in the (c) spring and (d) summer.

Legend:

▬ northern pike, - - - walleye, — — goldeye, ── lake whitefish, - · - · white sucker,
┈┈ longnose sucker, and - - - flathead chub

Seasons: 1= spring, 2=summer, 3=fall
Predators: N=northern pike, W=walleye, LK=lake whitefish, WT=white sucker, LN=longnose sucker, G=goldeye, F=flathead chub
Fish Prey: BR=burbot, EM=emerald shiner, FH=flathead chub, GD=goldeye, LK=lake whitefish, 9SB=ninespine stickleback, NP=northern pike, SC=sculpin, SK=sucker, SP=spottail shiner, TP=trout-perch, WL=walleye
Invertebrate Prey: Am=Amphipoda, Cer=Ceratopogonidae, Ch=Chironomidae, Cx=Corixidae, Dp=other Diptera, Dy=Dytiscidae, Ep=Ephemeroptera, Gp=Gastropoda, Pl=Plecoptera, Os=Ostracoda, Ter=terrestrial insects, Tr=Trichoptera, Zy=Zygoptera
Other Prey: VT=other vertebrates, Veg=plant material, det=detritus

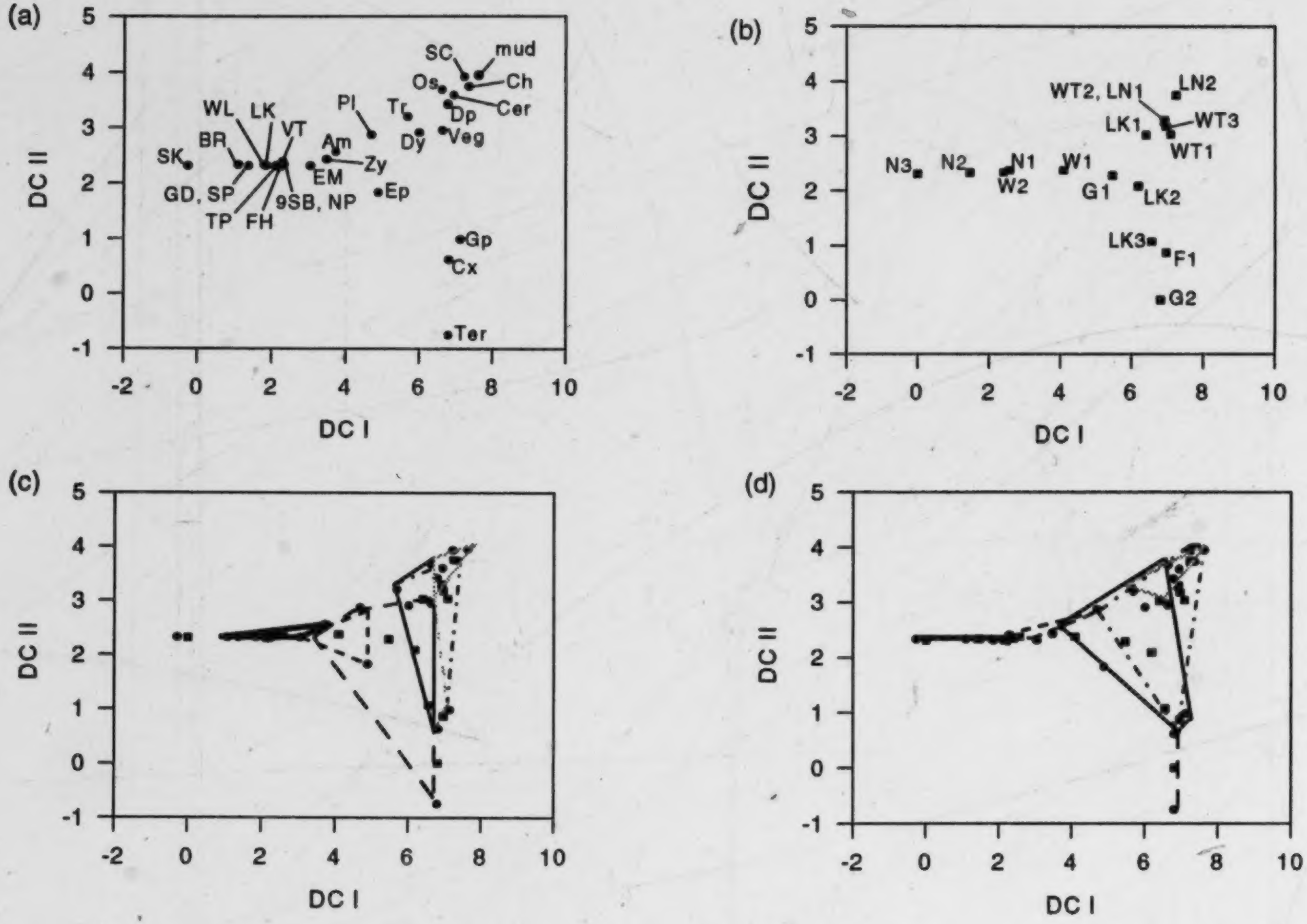
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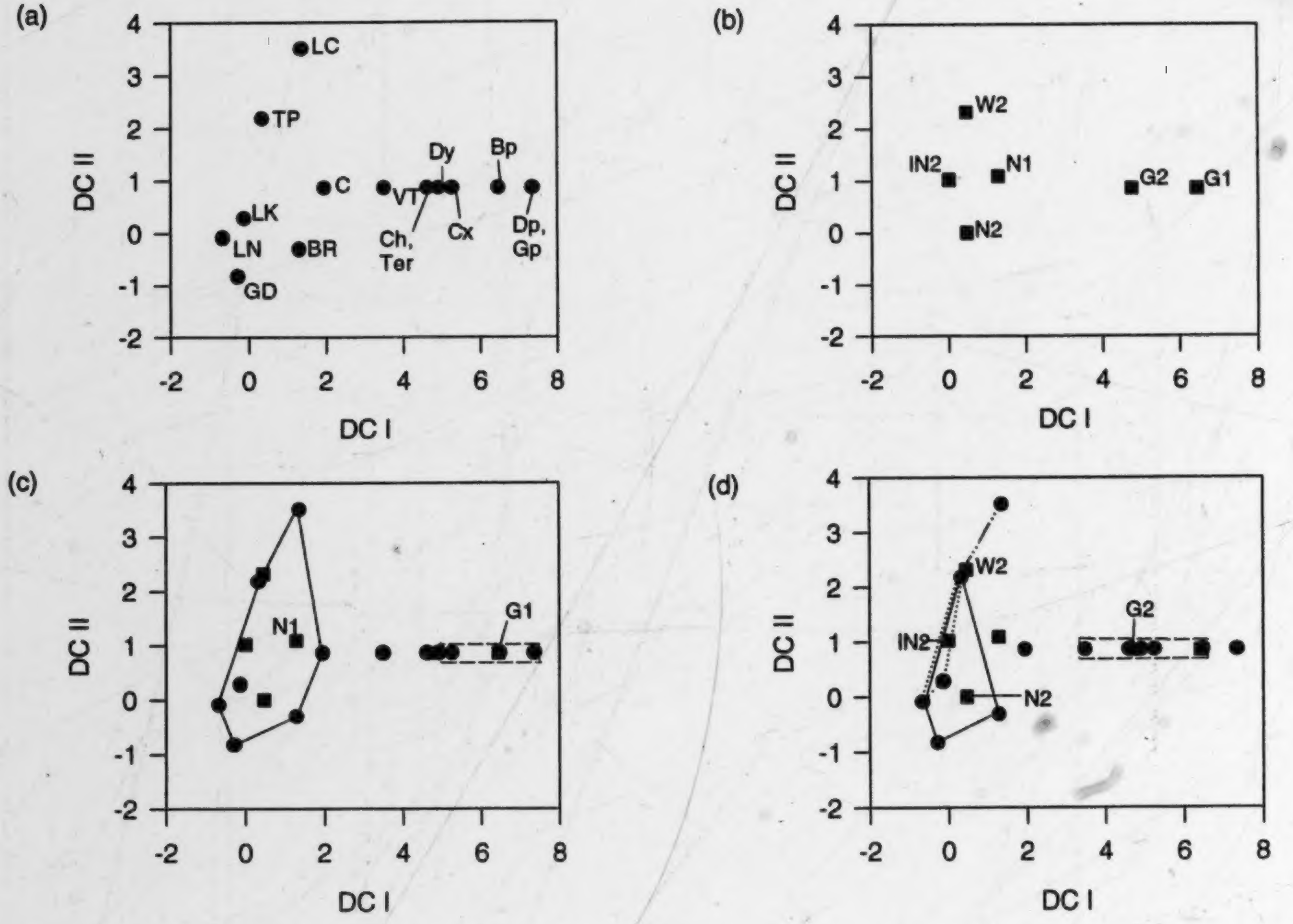
Figure 2-21. Detrended Correspondence Analysis of trophic relations in the Slave Delta, 1995. (a) Prey species scores, and (b) Predator species scores. Polygons that encompass prey with RI values >5% for each predator in the (c) spring and (d) summer.

Legend:

—— northern pike, - · - walleye, ······ inconnu, and — — goldeye

Seasons: 1= spring, 2=summer
Predators: N=northern pike, W=walleye, IN=inconnu, G=goldeye
Fish Prey: BR=burbot, C=cisco, GD=goldeye, LC=lake chub, LK=lake whitefish, LN=longnose sucker, TP=trout-perch
Invertebrate Prey: Bp=Branchiopoda (clam shrimp), Ch=Chironomidae, Cx=Corixidae, Dp=other Diptera, Dy=Dytiscidae, Gp=Gastropoda, Ter=terrestrial insects,
Other Prey: VT=other vertebrates (rodents)


(a)
(b)
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DC I
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Discussion

Fish Species Composition of the Slave River system

The Slave River system consists of 23 fish species, representing 11 different families; of those, six species were rare in this study. This was similar to the findings of previous work in the Slave River system (Tripp *et al.* 1981; McCleod *et al.* 1985). On the basis of habitat heterogeneity, which has been found to influence species diversity (Angermeier 1985, Keast 1978), it would be expected that species diversity would be highest in the Slave Delta, followed by the Salt River, then the Slave River. After rare species were excluded, the Slave Delta had the highest species diversity (15 species) followed by the Slave River (14) and the Salt River (13). Differences found between the species diversity of the Slave and Salt Rivers were probably due to the large difference in channel size.

Overall, the Slave River comprises roughly half of the total species present in the Mackenzie basin (23 versus 53) (Bodaly *et al.* 1989). However, in comparison with tropical and temperate river systems, species diversity of this northern system is much lower when standardized on the basis of watershed area (Welcomme 1985; Bodaly *et al.* 1989). These differences are primarily due to increased climatic severity in northern regions, such as a shorter growing season and lower water temperatures (Morin *et al.* 1981; Bodaly *et al.* 1989) and to postglacial dispersion patterns (Morin *et al.* 1981; Lindsey and McPhail 1986).

Two groups of fishes were represented in the Slave River system, resident species and migratory species. This result was not surprising since the mainstems of large rivers in many different geographical locations have been found to be used primarily as corridors for migratory fishes (Bayley and Petrere 1989; Bodaly *et al.* 1989; Novoa 1989; Roy 1989). With the option to undertake migrations, fish can select distinct spawning areas and/or feeding areas (Bodaly *et al.* 1989). However, the number of truly migratory species that use the river for only part of their life history was quite low in the Slave River (2 species) compared with systems connected to estuaries and marine coastal regions (Bodaly *et al.* 1989), which often represent more productive feeding areas. Although resident species complete their life cycle within the river, the high catch-per-unit-effort observed in the spring suggests that even resident species migrate within the river, possibly to preferred spawning or feeding areas.

Variability of habitat use within the Fish Assemblages of the Slave River System

The community-level analysis of habitat use illustrated that the fish assemblages among the three study areas were ecologically distinct. Since the species composition within these regional assemblages were similar (at least in this analysis), each species must therefore be versatile in their ability to use a variety of different habitat regimes. Discharge was the main habitat factor distinguishing the Slave River and Delta assemblages from the Salt River assemblage, probably due to the large difference in channel size and morphology. The distinction between the Slave River and its delta was due to the association of the Slave Delta fish assemblage with vegetation. However, when species-habitat associations were considered within each of the study areas, finer-scaled differences in habitat use were also evident among individual species.

Northern pike are found in a wide variety of habitat types, however they generally prefer clear, heavily vegetated waters (Scott and Crossman 1973). Vegetated areas allow for concealment of these visual sit-and-wait, opportunistic predators (Nursall 1973, Christiansen 1976, Turner 1984. Studies by Diana *et al.* (1977) and Turner (1984) found that northern pike in northern Alberta lakes were associated with shallow, vegetated waters approximately 90% of the time. Within the Slave River system, northern pike were most closely associated with shallow, vegetated areas when this type of habitat was available.

Walleye are also adaptable to a wide range of environmental situations, but are mainly found in large, shallow, turbid lakes or large turbid rivers (Scott and Crossman 1973; Colby *et al.* 1979). Temperature is often considered one of the most important factors influencing walleye distributions (Spangler *et al.* 1977; Colby *et al.* 1979; Bryan *et al.* 1995). In particular, temperature cues spawning migrations and spawning events (Colby *et al.* 1979). In the Slave River, the highest abundance of walleye were associated with low water temperatures and increased discharge, which may be important in cueing spring spawning events. Another important factor influencing walleye distributions is light intensity (Scott and Crossman 1973, Colby *et al.* 1979). Due to extremely sensitive retinas to light, walleye in many lakes have been found to seek shelter among shoals of large boulders or sunken trees during daylight hours (Colby *et al.* 1979). These types of habitat structures are often not present in flowing water systems such as the Slave River, however, due to the extreme turbidity of the Slave River and its delta, walleye activity likely would not be restricted by light. Generally, walleye are found at depths of 1-15 m, and they tend to avoid dense submergent vegetation (Colby *et al.* 1979); this was also the case in the Slave River. Overall, walleye in the Slave River system were most often associated with moderate distances from shore and little or no vegetation, and in faster currents and greater discharges within the mainstem.

Of the Slave River migratory species that reside in Great Slave Lake, inconnu are most often associated with inshore depths of 10 m, occasionally invading open-water, whereas lake whitefish inhabit offshore depths (Rawson 1951). Fuller (1955) also found inconnu primarily residing in moderately shallow waters and concluded that depth seemed to be the main factor influencing their distribution in Great Slave Lake. Inconnu within the Slave River were also associated with moderately shallow depths but lower discharges and water temperatures were the most important habitat variables. During the fall spawning migration from Great Slave Lake to the Rapids of the Drowned at Fort Smith, it is most probable that both inconnu and lake whitefish migrate along the shoreline through back-eddies, since the slower current of those areas would be energetically less costly.

Goldeye and flathead chub are often associated with large, turbid rivers; goldeye can also be found in the muddy shallower waters of some larger lakes and connecting tributaries (Scott and Crossman 1973). Both species are generally associated with open-water (Scott and Crossman 1973), which was similar to the findings in the Slave River. Both goldeye and flathead chub had their highest abundance during the spring when water temperatures were low, and discharge and current were high; it is during this time that these species aggregate to spawn. Goldeye have been found to be unaffected by sedimentation or fluctuating water levels (Nelson and Walburg 1977), thus turbidity and changes in discharge may not be critical in influencing goldeye distributions. Within the Slave River and the Delta, goldeye scores in the ordination were positioned near the origin, indicating that there was no dominant habitat variable influencing the distribution of goldeye. However, in the Salt River, goldeye were strongly associated with the deeper, less vegetated sections of this shallow river. As for flathead chub, very little is known about the ecology of this species. In the Slave River, flathead chub were associated with low water temperatures, offshore distances and moderately fast currents. Similar habitat associations were found in the Salt River, although flathead chub were not common in the Salt River.

White suckers are usually found in the warmer waters of shallow lakes or shallow bays and tributaries of larger lakes, generally within the top 6 to 9 m (Scott and Crossman 1973). Rawson (1951) reported that white suckers do not live within the lake proper of Great Slave Lake, rather in the shallow, warm bays and associated tributaries. However, longnose suckers, which prefer clear, cold water, are commonly found at depths of 10 to 20 meters within Great Slave Lake. Rawson (1951) concluded that these two sucker species probably compete very little for food and space in Great Slave Lake. In the Slave River system, these two species only coexisted within the Salt River. Distance from shore, which could also be related to depth, did not seem quite as important for these two species in the Salt River; however, temperature seemed to be the most important factor segregating these two sucker species. Depth segregations as observed in Great Slave Lake, are probably not a contributing factor in the Salt River since average depths range from 1 to 2 m and a maximum width of 60 m.

In summary, results from the habitat analyses showed that the distributions of most species were associated with a combination of habitat variables. However, few species appeared influenced by the same combinations of habitat variables, thus interactions in habitat use are probably low.

The diets of resident and migratory piscivores

Northern pike and walleye are generally considered piscivorous predators, often being the top predators of aquatic ecosystems (Lawler 1965; Scott and Crossman 1973; Colby *et* al. 1979; Diana 1979). Both species are also generalist feeders in many systems (Scott and Crossman 1973; Christiansen 1976; Turner 1984; Chapman *et al.* 1989; Bryan *et al.* 1995), although some studies show that both these predators can exhibit size-selective predation (Colby *et al.* 1979; Hart and Hamrin 1988; Wahl and Stein 1988). Northern pike and walleye from the lower Slave River system both exhibited a generalist feeding strategy throughout the three sampling locations. It is not surprising that these visual predators (Scott and Crossman 1973) are opportunistic foragers in the Slave River, since visibility is greatly reduced by turbidity and a steady current. Northern pike and walleye in the Slave River system consumed not only fish but also aquatic invertebrates; northern pike also occasionally ate terrestrial vertebrates such as rodents, snakes and birds. Many studies have documented terrestrial vertebrates in the diet of northern pike (Scott and Crossman 1973; Jones *et* al. 1978; Bond 1980), however, only a few studies have examined the importance of aquatic invertebrates in the diet of northern pike (Christiansen 1976; Chapman *et al.* 1989).

A high proportion of empty stomachs were documented throughout all seasons for both predators, generally ranging from 50 to 88% during a given time of the year. Although walleye occasionally regurgitate their stomach contents when caught in gillnets (per. obs.), a high proportion of empty stomachs is not atypical for many piscivores (Lawler 1965; Christiansen 1976; Jones *et al.* 1978; Tripp and McCart 1979; Turner 1984).

Variations in the diet composition of both northern pike and walleye were evident among the three study areas. These three study areas represented three different types of habitat, and the composition of prey species varied slightly between each area. Prey richness for both predators was highest in the Salt River and lowest in the Slave Delta. One might expect greater diet richness in areas of greater habitat diversity, particularly for generalist feeders, since a greater richness of prey may also be available in more heterogeneous environments (Keast 1978). As expected diet richness was high in the Salt River, however, I was surprised to find it lowest in the Slave Delta. The low richness observed in the Slave Delta may have simply been due to the lower sampling effort there compared with the other two study areas.

Seasonal dietary variation was also evident within each of the three study areas. Most shifts in diet corresponded to changes in the availability of various prey in the environment at a given time, which is typical for opportunistic feeders, including northern pike (Christiansen 1976; Turner 1984).

In the Slave River near Fort Smith, the importance of Arctic lamprey and flathead chub in the diets of the piscivores during the spring corresponded to expected peaks in their abundance at that location. Arctic lamprey are spring/early summer spawners (late May to early July) (Scott and Crossman 1973) and, although not susceptible to gillnets, are probably found in greater abundance at that time. Similarly, flathead chub had a much higher abundance during spring as compared with the remaining sampling periods (Figure 5), probably due to aggregations prior to spawning. Consistent with these findings, flathead chub in the Athabasca River system were the most important prey item for northern pike at this time, coinciding with a peak in their catch-per-unit-effort (Tripp and McCart 1979).

Aquatic invertebrates were an important part of the diet for northern pike and walleye during the spring in the Salt River and to a lesser extent in the Slave River. Few studies have reported aquatic invertebrates as a major part of the northern pike diet during this time, and all reports are from lake systems (Christiansen 1976; Chapman *et al.* 1989). In contrast, invertebrate feeding by walleye, particularly in the spring, has been well documented (Kelso 1973; Swenson 1977; Colby *et al.* 1979; Johnson *et al.* 1988; Bryan *et al.* 1995). Colby *et al.* (1979) suggested that in some lakes, walleye are forced to feed on aquatic invertebrates when forage fish are scarce. Limited beach seining in spring did show much lower numbers of forage fish compared with summer, when young-of-the-year fish appeared. As well, many aquatic invertebrates, such as the late instars of ephemeropterans, plecopterans, odonates and amphipods, are very abundant in spring, making them very accessible prey items (Keast 1977; Christiansen 1976).

In the Slave and Salt Rivers during summer, the importance of fish, particularly small fish, increased substantially in the diets of northern pike and walleye. A similar increase in small fish prey was observed in northern pike from a northern lake (Christiansen 1976). This increase could simply be due to an increase in the abundance of small fish and consequently an increase in their availability. By August, young-of-the-year (YOY) fish would have grown to a size that would likely make them profitable prey; these YOY are also possibly moving from safer very shallow waters to deeper, less safe waters where the majority of predators may be found (Power 1987). As well, catches in beach seines showed an increase in other important small-bodied prey species during the summer, particularly in the Salt River, consistent with studies on the Athabasca River (Tripp and McCart 1979; Bond 1980; Bond and Berry 1980) and elsewhere (Paetz and Nelson 1970; Scott and Crossman 1973).

During the fall, northern pike had a much higher diversity of prey species than walleye, although both species ate very few fish at this time. Northern pike used both deep-dwelling species, such as burbot and lake whitefish, as well as some of the same shallow-dwelling species taken in summer.

Although prey size generally increases with predator size for northern pike and walleye (Frost 1954; Popova 1967; Parsons 1971; Christiansen 1976; Forsythe and Wrenn 1979; Hart and Connellan 1984), relationships observed in the field often depend upon the availability of various size-classes of prey to the predators. In the Slave River system, northern pike exhibited a significant increase in prey length with increased predator length, with the average prey being 22% of the length of the predator; however, larger northern pike also continued to consume small prey items. The average prey-predator size relation for northern pike in the Slave River system was similar to those reported by Nursall (1973) and Christiansen (1976). Walleye in the Slave River system also exhibited increases in prey length with increased predator length, although the correlation was not as strong as with northern pike. The consumption of small prey exhibited by all sizes of northern pike and walleye might be expected in a system such as the Slave River. Given the high turbidity of the Slave River, and consequent reduced visibility, predators must probably resort to an opportunistic feeding strategy.

Adult burbot are mainly piscivorous, whereas juvenile burbot often consume more aquatic invertebrates and some small fish (Hewson 1955; Lawler 1963; Chen 1969; Tripp *et al*. 1981). A large proportion of the burbot captured in the Slave River had empty stomachs. However, adult burbot were only caught in significant numbers during December, under the ice, using set lines. Set lines are the most efficient method for catching burbot during the early winter congregations and are used by local fishermen for this purpose. However, collecting fish for diet analysis using baited set lines may have selected for fish with empty stomachs, thus biasing the results. Also, many fish species, including burbot, do not feed just prior to and during spawning (Pullianen and Korhonen 1990).

In contrast, a high number of juvenile burbot caught in gillnets during the summer and fall, had prey in their stomachs. These smaller burbot fed on YOY longnose sucker, ninespine stickleback, amphipods and plecopteran nymphs, which is consistent with earlier reports of the diet of young burbot less than 500 mm (Chen 1969; Scott and Crossman 1973; Tripp *et al.* 1981).

Inconnu is an arctic and subarctic species with a distribution in North America from the Bering Sea eastward to the Anderson River and south to Great Slave Lake and it's tributaries. Inconnu are abundant in the Mackenzie system, ranging from the Mackenzie River delta to the Rapids of the Drowned on the Slave River at Fort Smith, Northwest Territories (Scott and Crossman 1973; McLeod *et al.* 1979). Inconnu from this study area reside in Great Slave Lake for most of the year and are only present in the Slave River during the fall spawning period. Spawning migrations through the Slave Delta were initiated at the beginning of August for both years. During this time, 44% of the inconnu caught had stomach contents, considerably higher than the 16% found by Tripp *et al.* (1981) during the same time period. Upon reaching the Slave River near Fort Smith, 300 km upstream of the Delta, fewer inconnu (26%) contained prey items. Immediately prior to the peak spawning period in September, inconnu ceased feeding, based on the proportion of empty stomachs. Alt (1969, 1987) found that inconnu in the Kobuk and Chatanika Rivers, Alaska all had empty stomachs throughout the spawning migration. However, more similar to our findings, Petrova (1976) found that some inconnu from the Irtysh River Basin in Siberia were still feeding during the spawning migration, but ceased feeding thereafter.

The diets of invertebrate feeders

Based on CPUE and analyses of stomach contents, it appears that there are three distinct groups of lake whitefish in the Slave River system. First, immature lake whitefish were resident in the Salt River and feeding throughout the open-water sampling periods. Second, non-feeding, migratory spawners were present in the main stem of the Slave River during late summer and throughout the fall. Other studies on the Slave and Athabasca Rivers have also found that lake whitefish cease feeding during the spawning season (McLeod *et al.* 1979; McCart *et al.* 1977; Bond 1980; Tripp *et al.* 1981), although Jones *et al.*(1978) found that most lake whitefish captured in the Athabasca River during the spawning season were gorged with whitefish eggs. Third, a peak in lake whitefish catch effort during late May and early June suggests that some of the fall spawning fish may have overwintered near the spawning grounds before migrating back to Great Slave Lake. All of those fish also had empty stomachs. Tripp *et al.* (1981) also found that lake whitefish were still relatively abundant in the Slave River near Fort Smith after the spring break-up and from tagging data suggested that some of these overwintered there after spawning. Similarly, Bond (1980) reported a spring peak in lake whitefish catches in the Athabasca River, again suggesting that some lake whitefish overwinter at the spawning grounds.

As a result, the diet of lake whitefish presented here, consisting of a wide variety of prey, but primarily ostracods and corixids, was only representative of immature fish caught in the Salt River, but is nevertheless consistent with lake whitefish diets in many other systems (Scott and Crossman 1973; Tohtz 1993).

Seasonal changes in the diet of the juvenile lake whitefish often corresponded to the changing availability of prey organisms in the environment, particularly for the dominant prey, ostracods and corixids. Ostracods, the dominant prey in the spring, hatch at this time (Delorme 1991), and, along with oligochaetes, dominated springtime macroinvertebrate samples taken in the Slave River Delta (Tripp *et al.* 1981). The corresponding decrease in the importance of ostracods during the summer may be attributed to declines in abundance due dropping water levels; in many systems, ostracods are absent throughout the summer due to desiccation (Delorme 1991). In the Slave River Delta, Tripp *et al.* (1981) found no ostracods were present in the fall sampling. During July and August, the amount of vegetation in the Salt River increased considerably, providing suitable habitats for a number of aquatic invertebrates such as gastropods, amphipods, corixids, and the larvae of trichopterans and dipterans (Wiggins 1977; Tripp *et al.* 1981; Keup 1988). Similarly, Tripp *et al.* (1981) found that corixids were absent in the spring sampling, but were dominant in August and the fall. Thus, the seasonal patterns of abundance in the benthic macroinvertebrate community, as measured in the Slave River Delta (Tripp *et al.* 1981) were reflected by most of the results of the stomach analysis of lake whitefish in the Salt River.

Goldeye were the most common resident fish species in the lower Slave River near Fort Smith throughout the open water sampling periods, although they were less abundant in the Slave Delta and the Salt River. Goldeye in the Slave River system were generalist and opportunistic feeders, with spatial and seasonal variations in diet composition that were similar to those seen in other systems (Kennedy and Sprules 1967; Scott and Crossman 1973; Donald and Kooyman 1977; McCart *et al.* 1977; Munson 1978; Bond 1980).

Plecopterans were the most important prey during the spring and summer in the Slave River and during the spring in the Salt River, similar to what has been found in the Athabasca River (Tripp and McCart 1979; Bond 1980). Most plecopterans emerge in spring or early summer and thus would be more abundant at this time, compared with later in the season (Barton 1986). Corixids were also an important part of the diet during May and June, although their highest importance was attained in October. In contrast, Donald and Kooyman (1977) found that corixids were the most dominant prey item in adult goldeye throughout the open water period in the Peace-Athabasca Delta area. For all three of my study areas, the importance of terrestrial insects peaked in July and August, by which time many insects have emerged (Kennedy and Sprules 1967; Keup 1988). Because all plant material in goldeye diets was of allochthonous origin (i.e., seeds, needles, leaves), it was not surprising that the importance of this material was highest during spring, when the water levels were very high and shoreline debris is swept downstream (Barton 1980).

Flathead chub are most often associated with large, turbid rivers (Scott and Crossman 1973). Similar to the temporal pattern described for the Athabasca River (Bond and Berry

1980; Bond 1980) and Slave Delta (Tripp *et al.* 1981), they were most abundant in the Slave River during the spring and were present in much lower numbers throughout the remainder of the open-water period. Although it has been suggested that they move into tributaries to spawn (Scott and Crossman 1973; Bond 1980), most flathead chub were caught in the Slave River proper; only once were they observed in the Salt River. No adults were captured in the Slave Delta, although YOY and 1+ were caught there in beach seines.

The flathead chub from the Salt River ate primarily gastropods and corixids, whereas gastropods were absent from the diets of chub caught in the Slave River, probably due to unsuitable habitat in the much faster flowing Slave River. Instead, these chub displayed considerable seasonal variation in diet that resembled those of goldeye from the Salt River. Terrestrial insects increased considerably in importance in the diet during July and August, corresponding to the emergence of many aquatic and terrestrial larvae. Although there are slight differences in the diets of flathead chub in the lower Slave River compared with those reported from similar systems (Athabasca River and Slave Delta: McCart *et al.* 1977; Bond 1980; Tripp *et al.* 1981), the diet of flathead chub in each study appeared to correspond to the availability of prey in the environment.

Longnose suckers and white suckers were mainly present in the Slave River system during their spring spawning periods; the former were present in the Slave and Salt Rivers, while the latter were found only in the Salt River. Spring spawning peaks have also been observed in the Slave River Delta and the Athabasca River (McCart *et al.* 1977; Bond and Berry 1980; Tripp and McCart 1979; Tripp *et al.* 1981). Both species are benthic feeders, eating prey such as chironomids and trichopterans, as well as detritus. As well, longnose sucker ate ostracods whereas white sucker consumed corixids. Few other studies have quantified the diet of longnose and white suckers in large northern rivers, often because the stomach contents are too well digested to permit identification of individual food items. However, the diets of longnose and white suckers in the Athabasca River were of much lower diversity then those of the Salt River (Bond 1980).

Trophic Relations in the Slave River system

The pairwise and community-level analyses of diets suggested that trophic relationships within the fish assemblages of the Slave River system were generally low throughout all seasons. A moderate degree of overlap was attained by a few species-pairs, however, none exhibited a high degree of overlap. These results may be due to several factors. First, differences in morphology, especially mouth characteristics (*e.g.*, mouth width and gape) may lead to differential feeding styles and/or size-limitations (Keast and Webb 1966), and secondly, differential use of feeding habitats may also result in low degrees of dietary overlap. Among the top predators, differences in mouth morphology may contribute to reduced trophic relations between northern pike and walleye. Walleye may be more limited by the size of prey that can be consumed compared with northern pike, thus larger prey such as flathead chub and suckers, may be consumed by northern pike, but probably not for walleye. In the Slave Delta, trophic relations between northern pike and inconnu were probably minimal since inconnu are also size-limited to small fish prey, generally less than 100 mm in length (Fuller 1955; Petrova 1976). Diet overlap between inconnu and walleye were moderate during the summer season, however, this may over-estimate the true trophic relationship since very few inconnu were feeding during this time. Within the invertebrate feeders of the Slave River system, goldeye are the only species with a supra-terminal mouth position, which allows for effective feeding on surface prey, such as adult winged-insects and surface-drifting small rodents. Conversely, lake whitefish, and suckers have sub-terminal mouth positions adapted for effectively feeding on benthic-dwelling organisms. Although these later species are primarily benthic feeders, with the potential to have a common prey base, trophic relations are probably minimized due to differences in habitat use as observed in the previous habitat analyses.

Thus, potentially common prey that may be abundant during certain time periods, may not be readily accessible to all predators due to differences in morphology and differential habitat use (or seasonal patterns of feeding versus migration/spawning), by resulting in weak trophic relationships among fishes in an assemblage.

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Chapter 3. GENERAL DISCUSSION AND CONCLUSIONS

The Slave River system has a diverse composition of fishes (23 species) for an inland northern river. However, in comparison to tropical and temperate river systems, fish species diversity in this river and other northern river systems is generally quite low when standardized on the basis of watershed area (Bodaly *et al.* 1989; Welcomme 1985). These differences are primarily due to increased climatic severity in northern regions such as shorter growing seasons and lower mean daily water temperatures (Morin *et al.* 1980; Bodaly *et al.* 1989) and to postglacial dispersion patterns (Morin *et al.* 1980; Lindsey and McPhail 1986). Another factor influencing the distribution and abundance of fishes is the productivity of a system. Productivity of river systems is believed to be influenced by abiotic factors such as discharge rates, substrate type, channel morphology and the degree of turbidity (Welcomme 1985; Bodaly *et al.* 1989; Ryder and Pesendorfer 1989; Johnson *et al.* 1995). Since the productivity of large rivers is generally low, fish often use these waters as migration corridors to and from preferred spawning and/or feeding areas (Bodaly *et al.* 1989; Roy 1989). In the Slave River, there were a number of resident species and several migratory spawning species from Great Slave Lake. The number of migratory species in the Slave River (2 species) was quite low compared with systems connected to estuaries and marine coastal regions (Bodaly *et al.* 1989), which often represent more productive feeding areas. Although resident species complete their life cycle within the Slave River, their high abundance observed in the spring suggests that even resident species migrate within the river, possibly to preferred spawning or feeding areas. Also, it appeared that the Salt River plays an important role for the Slave River by providing a refuge and nursery area in which fish can feed and mature.

The three study areas, the Slave River near Fort Smith, the Slave Delta, and the Salt River, represented distinct habitat regimes, most notably in the amount of vegetation and discharge rates. The presence of many of the same species in each of the three regional areas indicates that these species are tolerant to a variety of different habitat regimes, and thus can be considered habitat generalists. Furthermore, results from the habitat analyses showed that most species were associated with a combination of habitat variables and few species were influenced by the same combinations of habitat variables, thus interactions involving habitat use are probably low.

All actively feeding species within and among the study areas exhibited seasonal variations in diet, feeding most commonly on suitable prey that was most abundant in the system at a given time, thus as with habitat use, most fish in the Slave River system could be considered generalist feeders. Most species in the Salt River exhibited a wider diet breadth compared with fishes in the Slave River, probably due to a greater habitat heterogeneity. Increased habitat heterogeneity often leads to increased species richness (Keast 1978; Angermeier 1985), and thus there would be a greater potential prey base for predators.

Northern pike and walleye were the top predators in the Slave River (Figure 3-1). However, northern pike had a much greater diet richness, exhibiting versatility in the diet as they consumed not only fish but also terrestrial vertebrates and aquatic invertebrates. Inconnu and burbot are also generally considered to be top predators, however, within the Slave River, they were only present during their spawning seasons, when little or no feeding occurred. Few invertebrate-feeding species were present within the Slave River, probably due to abiotic factors such as fast currents, high turbidity and little vegetation, which limit the distribution and abundance of aquatic invertebrate prey. In the Salt River, the top piscivore was again the northern pike (Figure 3-2). Walleye fed not only on fish but also consumed aquatic invertebrates such as plecopterans and ephemeropterans, which exceeded the relative importance of some fish prey, particularly in the spring. Compared with the Slave River, there was a much greater diversity of aquatic invertebrates, and consequently, there was also a greater diversity of invertebrate feeders.

Trophic relationships within the fish assemblages of the Slave River system were generally weak throughout all seasons, and no species-pair exhibited a high degree of overlap. This result may be unexpected given that most fish were generalist feeders taking prey on the basis of their availability, however, many of these fish have differential feeding styles or use different feeding habitats, which contributed to minimizing trophic relationships among co-occurring species.

It is very difficult in large, open systems, such as the Slave River, to determine the specific factors influencing the structure of fish assemblages, although abiotic factors are probably the main factors influencing assemblage structure in this system. Abiotic factors, such as discharge, turbidity, and temperature, all play major roles in the overall productivity of a system. In addition, these factors strongly influence the distribution and abundance of prey, which could ultimately influence the distribution and abundance of predators. However, biotic factors, such as differential food use, may also be important in the structure of these assemblages. My results showed that trophic relationships within the assemblages of the Slave River system were generally weak. Previous studies examining trophic relationships have suggested that low dietary overlap within a community may indicate that food partitioning could be occurring (Johnson and Dropkin 1993; Keast 1985). I believe that although abiotic factors may strongly influence the structure of fish assemblages in this system, combinations of biotic and abiotic factors are likely acting together on these assemblages.

In 1991, Northern River Basins Study initiated a number of studies to address the concerns from northern residents about the cumulative effects of development on the water and aquatic environments in the Peace-Athabasca-Slave river basins. One of the areas lacking extensive, integrative information was the quantification of patterns in food and habitat use among the fish assemblages of the lower Slave River. The results from this study should provide aquatic ecologists and environmental managers with a better understanding of important food and habitat variables for fishes within the Slave River system. More specifically, information from this study should contribute to a better overall understanding of the potential pathways that contaminants bio-magnify within the food web of the Slave River. This study has shown that the food webs within this system can be very complex, however, there is still limited knowledge of the feeding and habitat ecology of organisms in lower trophic levels (i.e., aquatic invertebrates, and forage fish). Further studies are needed to determine species diversity and abundance, and habitat requirements of aquatic invertebrates within the lower Slave River system. Results from the habitat analyses may also provide insight into the potential effects of physical alterations, such as those of hydroelectric dams, on fishes within this system.

It is my hope that this study will provide valuable information for future developments of management guidelines in the North, and will provide a strong foundation for future fisheries work on the Slave River and other, large northern rivers.

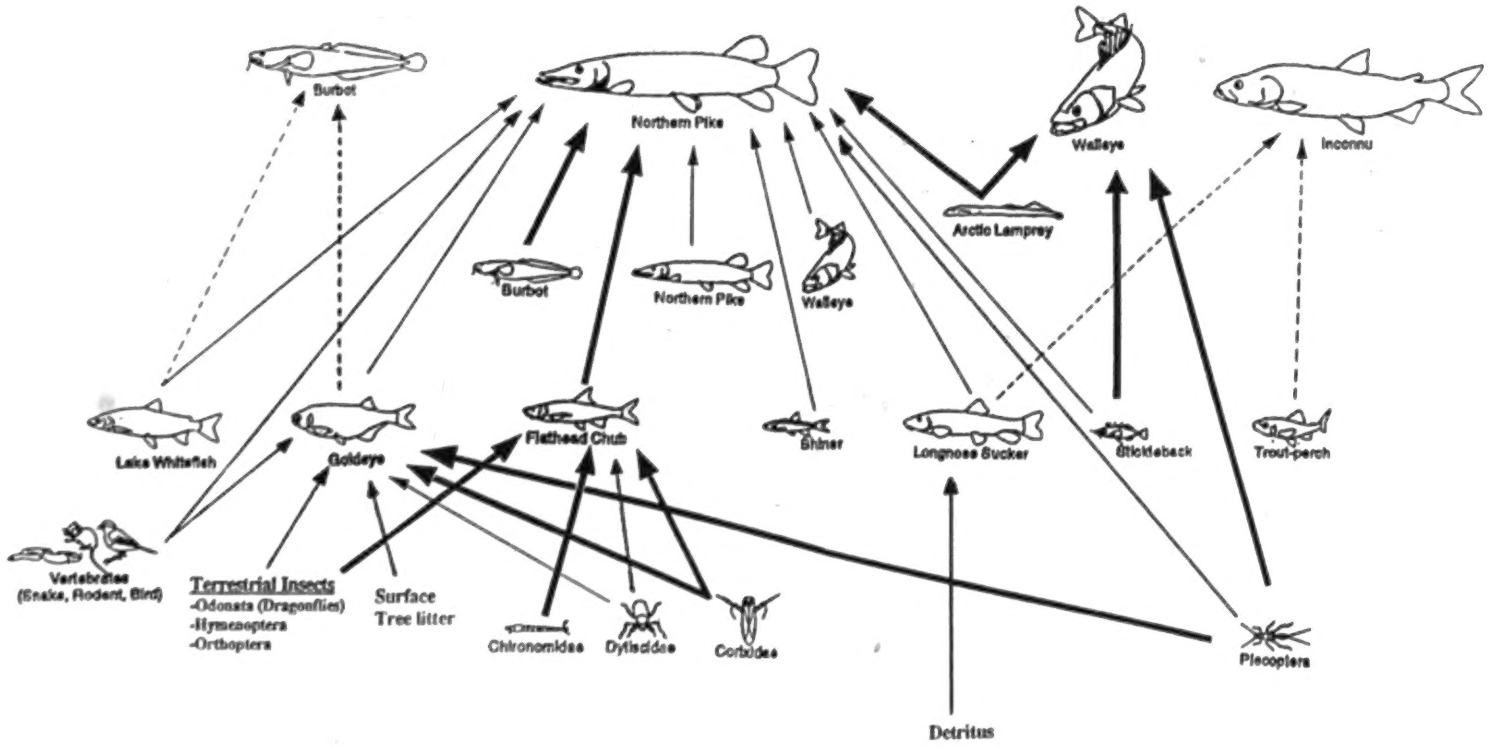
Burbot
Northern Pike
Walleye
Inconnu
Arctic Lamprey
Burbot
Northern Pike
Walleye
Lake Whitefish
Goldeye
Flathead Chub
Shiner
Longnose Sucker
Stickleback
Trout-perch
Vertebrates
(Snake, Rodent, Bird)
Terrestrial Insects
-Odonata (Dragonflies)
-Hymenoptera
-Orthoptera
Surface
Tree litter
Chironomidae
Dytiscidae
Corixidae
Plecoptera
Detritus

Figure 3-1. Food web in the lower Slave River, Northwest Territories, as represented in the diet analysis. Arrows indicate the direction of energy flow. Thick arrows indicate those prey which represented ≥10% Relative Importance (RI) in the diet, thin arrows indicate those prey which represented <10% RI, and dashed arrows indicate those few prey found when most stomachs examined were empty.

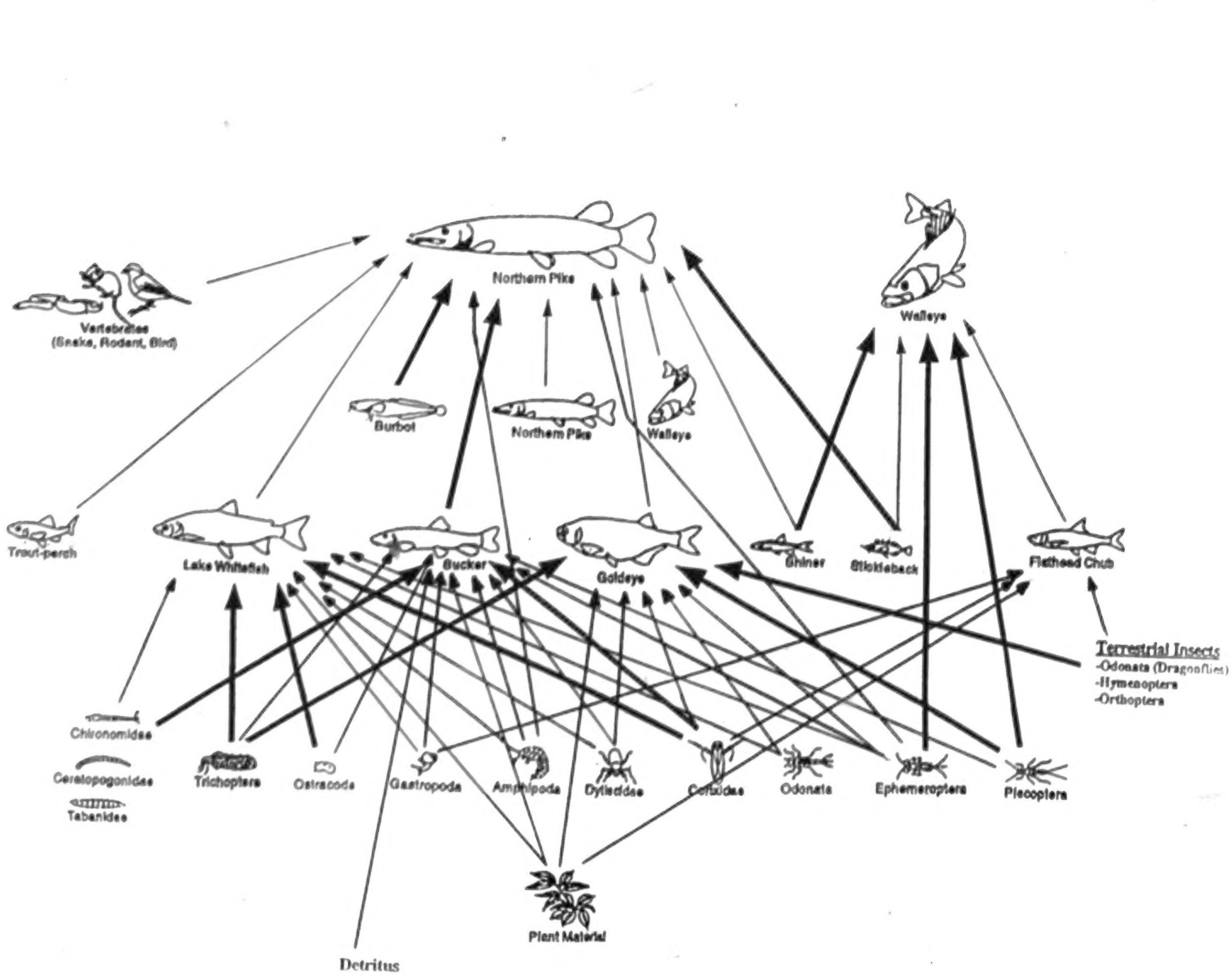
Vertebrates
(Snake, Rodent, Bird)
Northern Pike
Walleye
Burbot
Northern Pike
Walleye
Trout-perch
Lake Whitefish
Sucker
Goldeye
Shiner
Stickleback
Flathead Chub
Terrestrial Insects
-Odonata (Dragonflies)
-Hymenoptera
-Orthoptera
Chironomidae
Ceratopogonidae
Tabanidae
Trichoptera
Ostracoda
Gastropoda
Amphipoda
Dytiscidae
Corixidae
Odonata
Ephemeroptera
Plecoptera
Plant Material
Detritus

Figure 3-2. Food web in the Salt River, Northwest Territories, as represented in the diet analysis. Arrows indicate the direction of energy flow. Thicker arrows indicate those prey which represented >10% Relative Importance in the diet.

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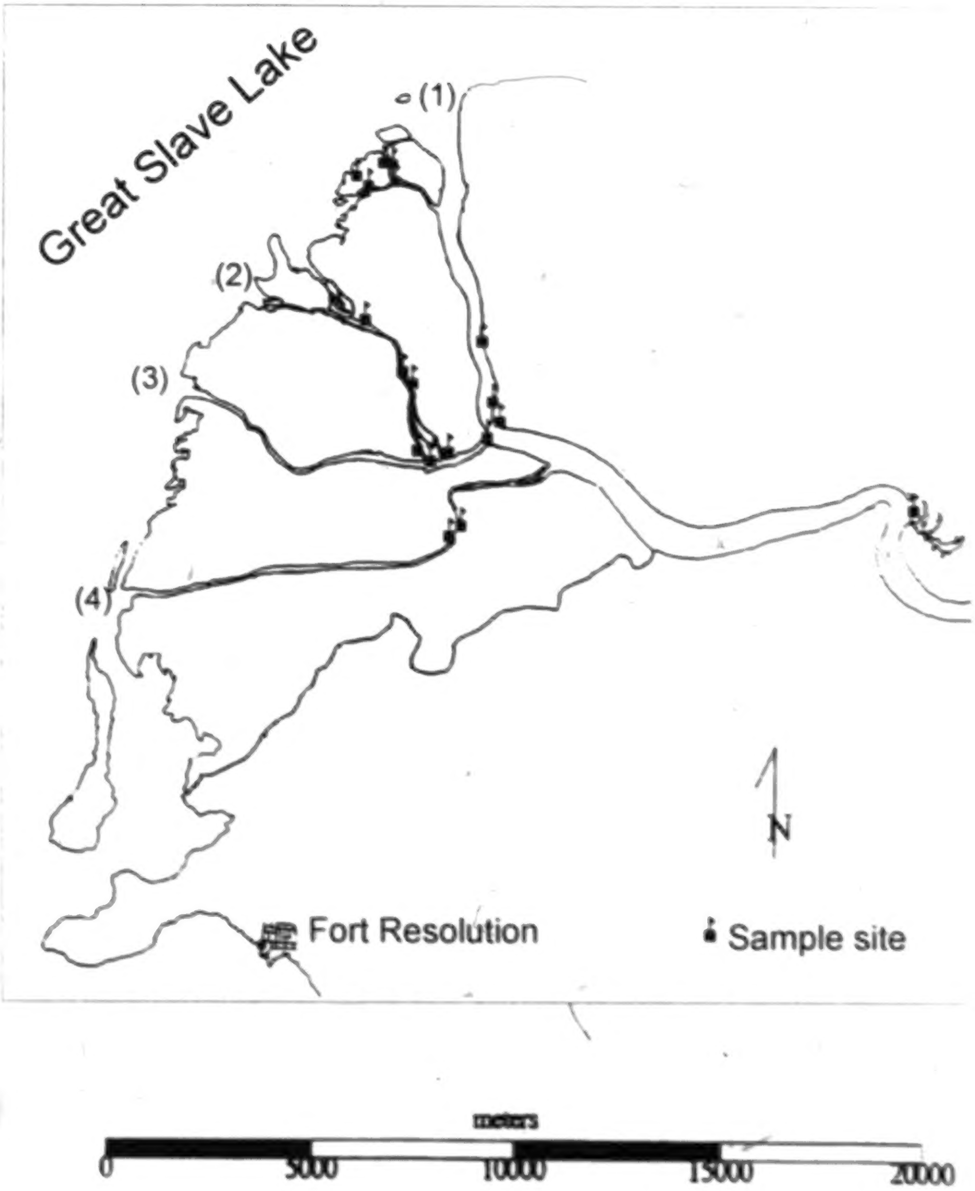
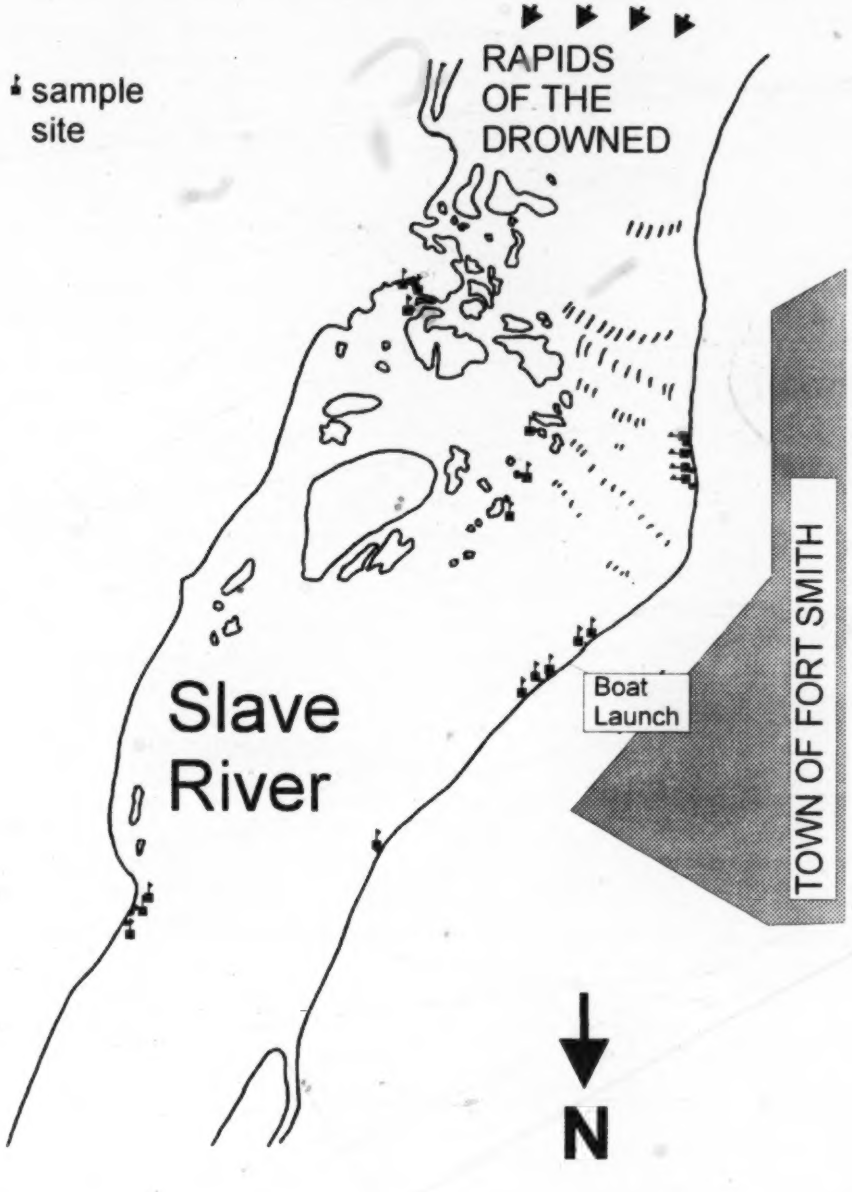
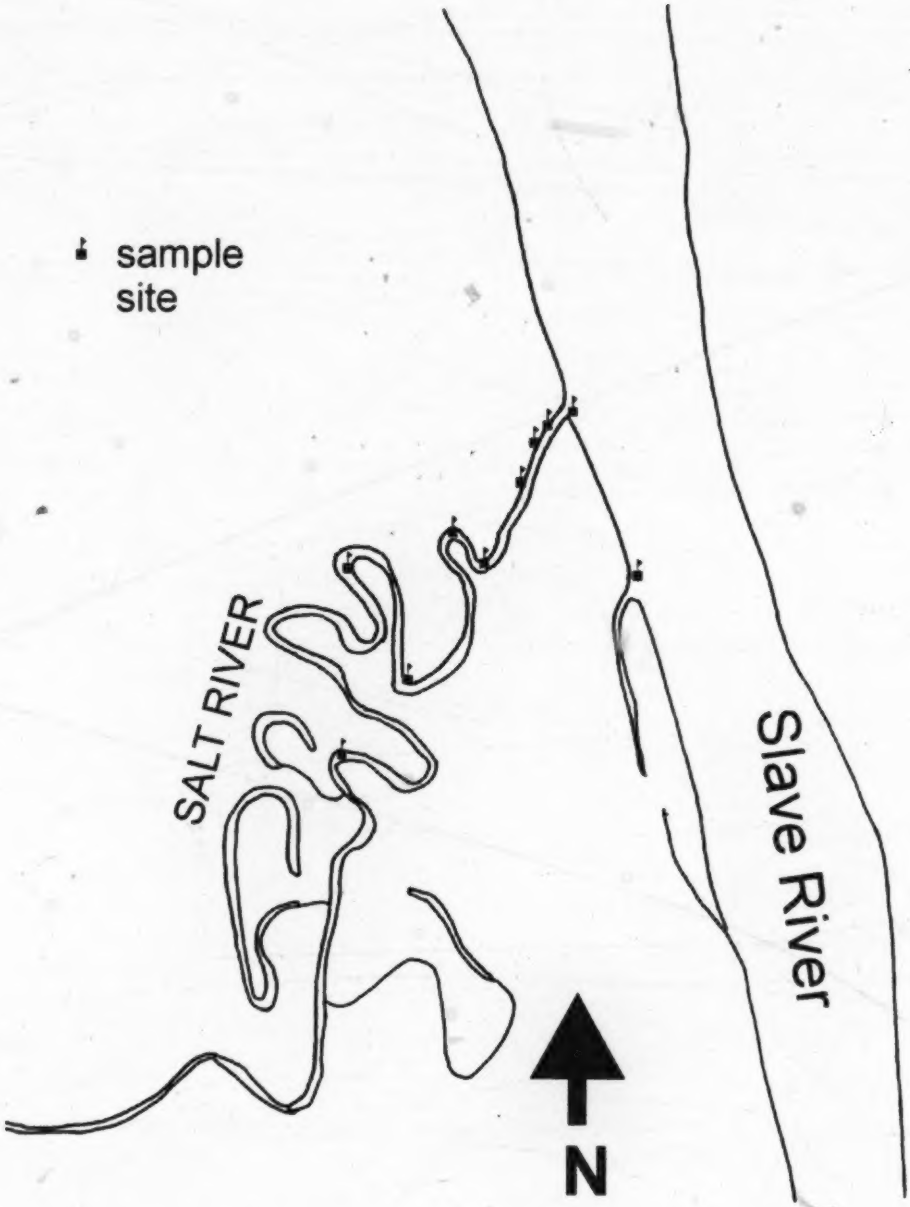

Great Slave Lake
(1)
(2)
(3)
(4)
N
Fort Resolution
Sample site
meters
0
5000
10000
15000
20000

Appendix A. Location of sampling sites on the Slave River Delta (modified from English et al. 1996), where (1)=ResDelta Channel, (2)=East Channel, (3)=Middle Channel, and (4)=Old Steamboat Channel.


sample site
RAPIDS OF THE DROWNED
Slave River
Boat Launch
TOWN OF FORT SMITH
N

Appendix B. Location of sampling stations on the Slave River at Fort Smith, Northwest Territories (modified from Tallman et al.1996).


sample site
SALT RIVER
Slave River
N

Appendix C. Location of sampling stations on the lower Salt River (from Tallman et al. 1996).

Appendix D. Percent number, mass, frequency of occurrence and Relative Importance (RI) of prey taxa in the diet of northern pike in the Slave River and Delta during the summer in 1994 (n=number of stomachs with prey suitable for the calculation of RI). Scientific names of fish prey are in Table 1.

Prey Items	% Number	% Mass	%Frequency of Occurrence	% RI n=26
northern pike	36.4	23.7	38.5	32.0
lake whitefish	9.1	49.0	11.5	22.7
walleye	12.1	0.0	15.4	8.9
suckers	3.0	19.9	3.9	8.7
spottail shiner	15.2	0.7	7.7	7.7
goldeye	6.1	5.6	7.7	6.3
flathead chub	6.1	0.9	7.7	4.8
emerald shiner	3.0	0.1	3.9	2.3
Ephemeroptera	3.0	0.0	3.9	2.2
Plecoptera	3.0	0.0	3.9	2.2
rodent	3.0	0.0	3.9	2.2

Appendix E. Seasonal variation in the Relative Importance (%) of prey for northern pike in the Slave River, Salt River and Slave Delta in 1995 and the summer season for the Slave River in 1994. Categories are based on the literature, and on gillnet and beach seine catches in the present study.

Prey Items	Slave River			Salt River			Slave Delta		Slave River 1994
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Summer
Deep-Dwelling fish:	**(87.8)**	**(41.1)**	**(52.3)**	**(0.0)**	**(17.6)**	**(18.7)**	**(36.7)**	**(58.9)**	**(27.5)**
flathead chub	57.5	11.8	0.0	0.0	0.0	0.0	0.0	0.0	4.8
Arctic lamprey	21.8	20.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
burbot	4.4	9.0	37.9	0.0	17.6	18.7	28.6	43.7	0.0
lake whitefish	0.0	0.0	14.5	0.0	0.0	0.0	8.1	15.1	22.7
large goldeye	4.1	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0
Shallow-Dwelling fish:	**(0.0)**	**(58.9)**	**(47.7)**	**(37.0)**	**(75.8)**	**(81.4)**	**(50.7)**	**(28.7)**	**(65.9)**
northern pike	0.0	18.9	0.0	18.9	0.0	0.0	0.0	0.0	32.0
burbot (YOY)	0.0	0.0	0.0	7.3	0.0	0.0	0.0	0.0	0.0
emerald shiner	0.0	14.6	17.0	0.0	2.1	0.0	0.0	0.0	2.3
trout-perch	0.0	14.2	5.1	0.0	4.3	0.0	29.0	11.5	0.0
walleye (YOY, 1+)	0.0	11.2	0.0	0.0	7.0	0.0	0.0	0.0	8.9
immature lake whitefish	0.0	0.0	0.0	10.9	13.7	0.0	0.0	0.0	0.0
ninespine stickleback	0.0	0.0	15.1	0.0	17.6	0.0	0.0	0.0	0.0
sucker (YOY, 1+)	0.0	0.0	10.5	0.0	17.6	81.3	0.0	11.5	8.7
small goldeye	0.0	0.0	0.0	0.0	11.4	0.0	0.0	0.0	6.3
spottail shiner	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	7.7
lake cisco	0.0	0.0	0.0	0.0	0.0	0.0	13.0	0.0	0.0
lake chub	0.0	0.0	0.0	0.0	0.0	0.0	8.7	0.0	0.0
Terrestrial Vertebrates:	**(0.0)**	**(0.0)**	**(0.0)**	**(31.7)**	**(2.4)**	**(0.0)**	**(12.6)**	**(0.0)**	**(2.2)**
Aquatic Invertebrates:	**(12.2)**	**(0.0)**	**(0.0)**	**(31.2)**	**(4.2)**	**(0.0)**	**(0.0)**	**(12.3)**	**(4.4)**
Plecoptera	12.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2
Amphipoda	0.0	0.0	0.0	17.0	2.1	0.0	0.0	0.0	0.0
Zygoptera	0.0	0.0	0.0	14.2	2.1	0.0	0.0	0.0	0.0
Ephemeroptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.3	2.2

Appendix F. Percent number, mass, frequency of occurrence and Relative Importance (RI) of prey taxa in the diet of walleye sampled from the Slave River and the Delta during July and August 1994 (n=number of stomachs with prey suitable for the calculation of RI). Scientific names of fish prey are in Table 1.

Prey Items	% Number	% Mass	% Frequency of Occurrence	% RI n=22
Fish:				**(79.6%)**
northern pike	25.0	63.7	18.2	33.6
sucker	18.8	9.3	27.3	17.4
trout-perch	9.4	6.1	9.1	7.7
walleye	9.4	0.0	13.6	7.2
flathead chub	6.3	7.5	9.1	7.2
spottail shiner	3.1	13.2	4.6	6.5
Aquatic Invertebrates:				**(20.4%)**
Ephemeroptera	6.3	0.1	9.1	5.0
Trichoptera	6.3	0.1	9.1	4.8
Plecoptera	6.3	0.03	9.1	4.8
Corixidae	6.3	0.02	4.6	3.4
Hymenoptera	3.1	0.00	4.6	2.4

Appendix G. Seasonal variation in the Relative Importance (%) of prey for walleye in the Slave River, Salt River and Slave Delta in 1995 and the summer season for the Slave River in 1994. Categories are based on the literature, and on gillnet and beach seine catches in the present study.

Prey Items	Slave River			Salt River			Slave Delta		Slave River 1994
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Summer
Deep-Dwelling fish:									
Arctic lamprey	0.0	52.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shallow-Dwelling fish:	**(53.2)**	**(47.4)**	**(100)**	**(30.1)**	**(93.7)**	**(0)**	**(0)**	**(90.2)**	**(79.6)**
Northern pike	12.6	11.1	0.0	0.0	0.0	0.0	0.0	0.0	33.6
Trout-perch	40.6	36.2	0.0	0.0	27.4	0.0	0.0	80.5	7.7
Ninespine stickleback	0.0	0.0	100.0	0.0	6.4	0.0	0.0	0.0	0.0
Shiner	0.0	0.0	0.0	30.1	31.3	0.0	0.0	0.0	6.5
Flathead chub	0.0	0.0	0.0	0.0	13.5	0.0	0.0	0.0	7.2
Sucker	0.0	0.0	0.0	0.0	6.6	0.0	0.0	0.0	17.4
Walleye	0.0	0.0	0.0	0.0	8.5	0.0	0.0	0.0	7.2
Lake chub	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.7	0.0
Aquatic Invertebrates:	**(46.8)**	**(0.0)**	**(0.0)**	**(69.9)**	**(6.3)**	**(0.0)**	**(0.0)**	**(9.8)**	**(20.4)**
Plecoptera	37.7	0.0	0.0	18.8	6.3	0.0	0.0	0.0	4.8
Amphipoda	9.1	0.0	0.0	7.1	0.0	0.0	0.0	0.0	0.0
Ephemeroptera	0.0	0.0	0.0	24.9	0.0	0.0	0.0	0.0	5.0
Trichoptera	0.0	0.0	0.0	6.1	0.0	0.0	0.0	0.0	4.8
Zygoptera	0.0	0.0	0.0	13.0	0.0	0.0	0.0	0.0	0.0
Diptera Larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.8	0.0
Corixidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4
Hymenoptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4

Appendix H. Percent number, mass, frequency of occurrence and Relative Importance (RI) of prey taxa in the diet of inconnu in the Slave River and Delta during 1994 (n=number of stomachs with prey suitable for the calculation of RI). Scientific names of fish prey are in Table 1.

Prey Items	% Number	% Mass	% Frequency of Occurrence	% RI n=10
northern pike	80.0	89.0	80.0	83.0
trout-perch	10.0	11.0	10.0	10.3
flathead chub	10.0	0.0	10.0	6.7

Appendix I. Percentage by number, mass, frequency of occurrence and Relative Importance (RI) of prey taxa in the diet of lake whitefish during August 1994 in the Salt River (n=number of stomachs with prey suitable for the calculation of RI).

Prey Items	% Number	% Mass	% Frequency of Occurrence	% RI n=9
Trichoptera	34.8	36.2	66.7	38.7
Dytiscidae	8.7	39.1	22.2	19.7
Corixidae	26.1	11.6	22.2	16.9
Chironomidae	13.0	12.3	22.2	13.4
Diptera	17.4	0.7	22.2	11.4

Appendix J. Seasonal variation in the Relative Importance (%) of prey for lake whitefish in the Slave River, Salt River and Slave Delta in 1995.

	Slave River			Salt River			Slave Delta	
Prey Items	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer
Aquatic Invertebrates:								
Amphipoda	0.0	0.0	0.0	1.9	9.0	0.0	ND	0.0
Ceratopogonidae	0.0	0.0	0.0	2.6	3.6	0.0	ND	0.0
Chironomidae	0.0	0.0	0.0	3.5	4.4	0.0	ND	0.0
Corixidae	0.0	0.0	0.0	13.2	27.7	67.5	ND	0.0
Diptera	0.0	0.0	0.0	2.2	5.5	0.0	ND	0.0
Dytiscidae	0.0	0.0	0.0	3.7	2.9	6.0	ND	0.0
Ephemeroptera	0.0	0.0	0.0	0.9	0.0	11.9	ND	0.0
Gastropoda	0.0	0.0	0.0	2.3	15.7	8.8	ND	0.0
Ostracoda	0.0	0.0	0.0	52.5	6.2	0.0	ND	0.0
Trichoptera	0.0	0.0	0.0	9.9	18.5	0.0	ND	0.0
Zygoptera	0.0	0.0	0.0	1.0	0.0	0.0	ND	0.0
Fish:								
Ninespine stickleback	0.0	0.0	0.0	1.8	4.2	0.0	ND	0.0
Plant material:	0.0	0.0	0.0	4.5	2.4	5.9	ND	0.0

Appendix K. Percent number, mass, frequency of occurrence and Relative Importance (RI) of prey taxa in the diet of goldeye during August 1994 in the Slave River (n=number of stomachs with prey suitable for the calculation of RI).

Prey Items	% Number	% Mass	% Frequency of Occurrence	% RI n=29
Terrestrial Insects:	**30.5**	**46.4**	**58.6**	**35.4**
Aquatic Invertebrates:				**(41.7%)**
Dytiscidae	16.2	8.2	24.1	12.7
Corixidae	21.0	0.9	20.7	11.1
Plecoptera	13.3	1.2	17.2	8.3
Trichoptera	5.7	0.3	17.2	6.1
Ephemeroptera	1.0	0.2	3.5	1.2
Chironomidae	1.0	0.0	3.5	1.2
Diptera larvae	1.0	0.0	3.5	1.2
Terrestrial Vertebrates:				**(11.9%)**
rodents	1.9	36.7	6.9	11.9
Fish:	**3.8**	**4.3**	**13.8**	**5.7**
Plant Material:	**4.8**	**1.8**	**13.8**	**5.3**

*Odonata (dragonflies), Orthoptera (grasshoppers) and Hymenoptera (fairy wasps)

Appendix L. Percent number, mass, frequency of occurrence and Relative Importance of prey taxa in the diet of goldeye in 1995, throughout all study sites and seasons (n=number of stomachs with prey suitable for the calculation of RI).

Prey Items	% Number	% Mass	% Frequency of Occurrence	% RI n=56
Aquatic Invertebrates:				**(77.7%)**
Branchiopoda	62.1	32.0	8.9	27.5
Corixidae	13.3	9.3	42.9	17.5
Plecoptera	3.0	1.4	33.9	10.2
Dytiscidae	1.6	2.5	23.2	7.3
Chironomidae	11.6	5.6	7.1	6.5
Gastropoda	1.9	4.3	3.6	2.6
Trichoptera	0.3	0.1	7.1	2.0
Amphipoda	1.7	1.0	3.6	1.7
Other Coleoptera	0.2	0.03	3.6	1.0
Other Diptera Larvae	0.04	0.04	1.8	0.5
Zygoptera	0.04	0.02	1.8	0.5
Ephemeroptera	0.04	0.01	1.8	0.5
Terrestrial Vertebrates:				**(11.6%)**
rodent	0.2	36.1	7.1	11.6
Terrestrial Insect[1] :	**3.8**	**7.5**	**19.6**	**8.3**
Plant Material:	**0.3**	**0.3**	**8.9**	**2.5**

[1] Odonata (dragonflies) and Hymenoptera (fairy wasps)

Appendix M. Percent number, mass, frequency of occurrence and Relative Importance (RI) of prey taxa in the diet of flathead chub in the Slave River, 1994 and 1995 (n=number of stomachs with prey suitable for the calculation of RI).

Prey Items	% Number	% Mass	% Frequency of Occurrence	% RI n=11
Aquatic Invertebrates:				**(81.7%)**
Dytiscidae	20.0	14.1	45.5	18.2
Plecoptera	13.3	18.8	36.4	15.7
Trichoptera	13.3	9.4	36.4	13.5
Corixidae	15.6	10.2	27.3	12.1
Coleoptera	8.9	12.5	27.3	11.2
Chironomidae	17.8	3.1	27.3	11.0
Terrestrial Insects:				**(18.3%)**
Hymenoptera	6.7	16.4	18.2	9.5
Orthoptera	4.4	15.6	18.2	8.8

Appendix N. Principal Component Analysis original data matrix for the output of Figure 2-7.

Species	**Location**	**Temperature** (°C)	**Discharge** ($m^3/s \div 100$)	**Current** (m/s)	**Distance from shore** (m)	**Vegetation** (1-10)
Flathead Chub	Salt River	17.37	00.03	00.09	09.33	00.08
Goldeye	Salt River	17.95	00.03	00.07	11.44	00.14
Lake Whitefish	Salt River	18.29	00.03	00.07	10.28	00.67
Longnose Sucker	Salt River	17.82	00.03	00.08	08.40	00.60
Northern Pike	Salt River	18.83	00.04	00.08	07.83	01.48
Walleye	Salt River	17.99	00.03	00.06	10.50	00.45
White Sucker	Salt River	19.43	00.03	00.06	09.23	00.57
Goldeye	Slave Delta	18.49	35.32	00.10	09.90	05.80
Inconnu	Slave Delta	17.80	31.42	00.10	09.80	05.40
Lake Whitefish	Slave Delta	19.10	37.65	00.12	10.50	05.00
Northern Pike	Slave Delta	18.58	35.82	00.11	07.43	09.35
Walleye	Slave Delta	18.68	40.04	00.11	10.11	05.56
Flathead Chub	Slave River	15.96	35.60	00.26	13.51	00.00
Goldeye	Slave River	17.28	35.37	00.22	12.58	00.00
Inconnu	Slave River	17.10	28.61	00.13	13.30	00.00
Lake Whitefish	Slave River	17.38	34.10	00.21	13.16	00.00
Longnose Sucker	Slave River	14.91	35.36	00.20	12.95	00.00
Northern Pike	Slave River	17.47	35.32	00.20	09.04	00.00
Walleye	Slave River	16.77	35.69	00.23	11.63	00.00

Appendix O(a). Principal Component Analysis original data matrix for the output of Figure 2-8a.

Species	Location	Temperature (°C)	Discharge ($m^3/s \div 100$)	Current (m/s)	Distance from shore (m)	Vegetation (1-10)
Flathead Chub	Slave River	15.96	35.60	00.26	13.51	00.00
Goldeye	Slave River	17.28	35.37	00.22	12.58	00.00
Inconnu	Slave River	17.10	28.61	00.13	13.30	00.00
Lake Whitefish	Slave River	17.38	34.10	00.21	13.16	00.00
Longnose Sucker	Slave River	14.91	35.36	00.20	12.95	00.00
Northern Pike	Slave River	17.47	35.32	00.20	09.04	00.00
Walleye	Slave River	16.77	35.69	00.23	11.63	00.00

Appendix O(b). Principal Component Analysis original data matrix for the output of Figure 2-8b.

Species	Location	Temperature (°C)	Discharge ($m^3/s \div 100$)	Current (m/s)	Dist. from shore (m)	Vegetation (1-10)
Goldeye	Slave Delta	18.49	35.32	00.10	09.90	05.80
Inconnu	Slave Delta	17.80	31.42	00.10	09.80	05.40
Lake Whitefish	Slave Delta	19.10	37.65	00.12	10.50	05.00
Northern Pike	Slave Delta	18.58	35.82	00.11	07.43	09.35
Walleye	Slave Delta	18.68	40.04	00.11	10.11	05.56

Appendix O(c). Principal Component Analysis original data matrix for the output of Figure 2-8c.

Species	Location	Temperature (°C)	Discharge ($m^3/s \div 100$)	Current (m/s)	Dist. from shore (m)	Vegetation (1-10)
Flathead Chub	Salt River	17.37	00.03	00.09	09.33	00.08
Goldeye	Salt River	17.95	00.03	00.07	11.44	00.14
Lake Whitefish	Salt River	18.29	00.03	00.07	10.28	00.67
Longnose Sucker	Salt River	17.82	00.03	00.08	08.40	00.60
Northern Pike	Salt River	18.83	00.04	00.08	07.83	01.48
Walleye	Salt River	17.99	00.03	00.06	10.50	00.45
White Sucker	Salt River	19.43	00.03	00.06	09.23	00.57

Appendix P. Detrended Correspondance Analysis original data matrix for the output of Figure 2-19: Trophic relations in the Slave River, where the rows are predators and the columns are prey taxa.

	AR	BR	EM	FH	GD	LK	LN	9SB	NP	TP	WL	Am	Ch	Col	Cx	Dy	Ep	Pl	Ter	Tr	Veg	VT
N1	0.22	0.04	0.00	0.58	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00
N2	0.20	0.09	0.15	0.12	0.00	0.00	0.00	0.00	0.19	0.14	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N3	0.00	0.38	0.17	0.00	0.00	0.14	0.10	0.15	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.41	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00
W2	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.25	0.08	0.00	0.47	0.04	0.00	0.13	0.00
G2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.16	0.00	0.49	0.26	0.00	0.06	0.00
G3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.10	0.05	0.00	0.05	0.00	0.00	0.12
F1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.16	0.12	0.20	0.00	0.21	0.07	0.20	0.00	0.00
F2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.07	0.14	0.16	0.00	0.10	0.29	0.07	0.00	0.00

Seasons: 1= spring, 2=summer, 3=fall

Predators: N=northern pike, W=walleye, G=goldeye, F=flathead chub

Fish Prey: AL=Arctic lamprey, BR=burbot, EM=emerald shiner, FH=flathead chub, GD=goldeye, LK=lake whitefish, LN=longnose sucker, 9SB=ninespine stickleback, NP=northern pike, TP=trout-perch, WL=walleye

Invertebrate Prey: Am=Amphipoda, Ch=Chironomidae, Col=other coleoptera, Cx=Corixidae, Dy=Dytiscidae, Ep=Ephemeroptera, Pl=Plecoptera, Ter=terrestrial insects, Tr=Trichoptera

Other Prey: VT=other vertebrates, Veg=plant material

Appendix Q. Detrended Correspondance Analysis original data matrix for the output of Figure 2-20: Trophic relations in the Salt River, where the rows are predators and the columns are prey taxa.

	BR	EM	FH	GD	LK	9SB	NP	SC	SP	SK	TP	VT	WL	Zy	Ep	Tr	Am	Cer	Ch	Cx	Dp	Dy	Gp	Os	Pl	Ter	Veg	D
N1	0.07	0.00	0.00	0.00	0.11	0.00	0.19	0.00	0.00	0.00	0.00	0.32	0.00	0.14	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	0.18	0.02	0.00	0.11	0.14	0.18	0.00	0.00	0.02	0.18	0.04	0.02	0.07	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N3	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W1	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.25	0.06	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00
W2	0.00	0.31	0.14	0.00	0.00	0.06	0.00	0.00	0.00	0.07	0.27	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00
LK1	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.10	0.02	0.03	0.04	0.13	0.02	0.04	0.02	0.52	0.00	0.00	0.05	0.00
LK2	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.09	0.04	0.04	0.28	0.05	0.03	0.16	0.06	0.00	0.00	0.02	0.00
LK3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.67	0.00	0.06	0.09	0.00	0.00	0.00	0.06	0.00
G1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.21	0.00	0.00	0.00	0.06	0.00	0.09	0.00	0.00	0.34	0.12	0.06	0.00
G2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00
F1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.51	0.00	0.00	0.10	0.09	0.00
WT1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.10	0.43	0.06	0.07	0.21	0.00	0.00	0.00	0.00	0.00
WT2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.06	0.30	0.11	0.11	0.05	0.05	0.00	0.09	0.00	0.00	0.00
WT3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.09	0.00	0.17	0.19	0.16	0.13	0.06	0.06	0.00	0.00	0.00	0.00	0.00
LN1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.03	0.04	0.00	0.00	0.00	0.05	0.16	0.03	0.03	0.23	0.38
LN2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.06	0.56

Seasons: 1= spring, 2=summer, 3=fall

Predators: N=northern pike, W=walleye, LK=lake whitefish, WT=white sucker, LN=longnose sucker, G=goldeye, F=flathead chub

Fish Prey: BR=burbot, EM=emerald shiner, FH=flathead chub, GD=goldeye, LK=lake whitefish, 9SB=ninespine stickleback, NP=northern pike, SC=sculpin, SK=sucker, SP=spottail shiner, TP=trout-perch, WL=walleye

Invertebrate Prey: Am=Amphipoda, Cer=Ceratopogonidae, Ch=Chironomidae, Cx=Corixidae, Dp=other Diptera, Dy=Dytiscidae, Ep=Ephemeroptera, Gp=Gastropoda, Pl=Plecoptera, Os=Ostracoda, Ter=terrestrial insects, Tr=Trichoptera, Zy=Zygoptera

Other Prey: VT=other vertebrates, Veg=plant material, D=detritus

Appendix R. Detrended Correspondance Analysis original data matrix for the output of Figure 2-21: Trophic relations in the Slave Delta, where the rows are predators and the columns are prey taxa.

	BR	GD	LC	C	LK	LN	TP	VT	Ep	Bp	Ch	Cx	Dp	Dy	Gp	Terr
N1	0.29	0.00	0.09	0.13	0.08	0.00	0.29	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	0.44	0.06	0.00	0.00	0.15	0.12	0.12	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W2	0.00	0.00	0.11	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN2	0.00	0.00	0.00	0.00	0.44	0.14	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.00	0.08	0.08	0.08	0.12	0.00
G2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.13	0.2	0.17	0.00	0.07	0.00	0.12

Seasons: 1= spring, 2=summer

Predators: N=northern pike, W=walleye, IN=inconnu, G=goldeye

Fish Prey: BR=burbot, C=cisco, GD=goldeye, LC=lake chub, LK=lake whitefish, LN=longnose sucker, TP=trout-perch

Invertebrate Prey: Bp=Branchiopoda (clam shrimp), Ch=Chironomidae, Cx=Corixidae, Dp=other Diptera, Dy=Dytiscidae, Gp=Gastropoda, Ter=terrestrial insects

Other Prey: VT=other vertebrates (rodents)